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Results of In-Air Testing of Metal Detectors

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Technical Report
DRES TR 2000-185
December 2000

National Defence Défense nationale

Canada

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This report is a part of the Canadian Contribution to the IPPTC (International Pilot Project for Technology Co-operation) project on metal detector evaluation.

Defence Research Establishment Suffield

Technical Report

DRES TR 2000-185

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Abstract

Canada participated in the International Pilot Project for Technology Co-operation (IPPTC) in landmine detection under the auspices of the Canadian Centre for Mine Action Technologies (CCMAT). The goal of this multinational project was to conduct various laboratory and field tests on a number of commercial metal detectors in their use as landmine detectors. Results of these tests will provide relevant information to potential sponsors and end users of such technology to help them make informed decisions about their equipment selection and use in humanitarian demining. This report presents the results of in-air laboratory tests, designed and led by Canada, and conducted at the Defence Research Establishment Suffield.

Résumé

Le Canada a participé au projet pilote international pour la coopération technologique (IPPTC), dans le domaine de la détection de mines terrestres, avec l'appui du Centre canadien des technologies de déminage (CCTD). L'objectif de ce projet multinational a été de soumettre à différents essais, en laboratoire et sur le terrain, un certain nombre de détecteurs de métaux commerciaux utilisés comme détecteurs de mines terrestres. Les résultats de ces essais fourniront aux éventuels commanditaires et utilisateurs finaux de cette technologie des renseignements utiles et les aideront à prendre des décisions éclairés sur le choix et l'usage du matériel qu'ils destinent au déminage humanitaire. Le présent rapport expose les résultats des essais en laboratoire effectués dans l'air ambiant, conçus et menés par le Canada, au Centre de recherches pour la défense Suffield.

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Executive summary

Canada participated in the International Pilot Project for Technology Co-operation (IPPTC) in landmine detection under the auspices of the Canadian Centre for Mine Action Technologies (CCMAT). Other participants were government agencies and research institutes from the U.S.A., the U.K., the Netherlands and the European Union. Under this project a number of laboratory and field tests were conducted on 29 commercial metal/mine detector models in order to provide relevant information to potential sponsors and end users of such technology to help them make informed decisions about their equipment selection and use in humanitarian demining.

This document presents the results of the In-Air Tests which were a part of the Canadian contribution to the IPPTC. The main purpose of these tests, conducted at the Defence Research Establishment Suffield (DRES), was to understand certain basic operational parameters of the detectors in a controlled laboratory environment. A total of six tests were performed. Four of these, namely, Calibration, Drift, Moisture and Sweep-Speed Tests measured the effect on a detector's performance of initial set-up procedure, electronic drift, water gathering on the detector head and the speed with which a detector is swept. Results showed that the effect these factors had on performance varied significantly among the detectors. The Sensitivity Test measured the ability of a detector to detect a variety of landmines and other targets. Results showed a large variation in the distance at which a target could be detected by the various models. The Scan Profile Test produced detector "footprints", which indicate how the detectability of a target may depend on its location with respect to the search coil. Contrary to claims by some manufacturers the data from this test showed that detector's footprint becomes smaller as the target distance increases.

Although a detector's ability to detect targets in air does not always indicate its ability to detect targets in soil, the results of the In-Air Tests will serve many useful purposes such as: provide data on the repeatability and stability of a detector's performance; compare detection distances of a variety of targets, thus revealing weaknesses in detectors that are optimized against a single target; identify detectors which do not have the minimum required detection distance for targets of interest; provide footprint data to determine search patterns to ensure desired coverage. The results could be used to verify the manufacturers' specifications, to avoid choosing detectors that are obviously inadequate, to explain results of operational trials, and to develop proper training and operating procedures. Data from these tests should be used in conjunction with the other IPPTC tests to choose detectors for a given situation.

Future evaluations of this nature should consider conducting additional tests to determine the effect of battery state, temperature and humidity, ambient electromagnetic noise and the operator on detector performance.

Y. Das, J.D. Toews , K. Russell, S. Lewis. 2000. Results of In-Air Testing of Metal Detectors. DRES TR 2000-185. Defence Research Establishment Suffield.

Sommaire

Le Canada a participé au projet pilote international pour la coopération technologique (IPPTC), dans le domaine de la détection de mines terrestres, avec l'appui du Centre canadien des technologies de déminage (CCTD). Les autres participants étaient des organismes gouvernementaux et des instituts de recherche des États-Unis, du Royaume-Uni, des Pays-Bas et de l'Union européenne. Dans le cadre de ce projet, 29 modèles de détecteurs de métaux ou de mines commerciaux ont été soumis à un certain nombre d'essais, en laboratoire et sur le terrain, pour fournir aux éventuels commanditaires et utilisateurs finaux de cette technologie des renseignements utiles et les aider à prendre des décisions éclairés sur le choix et l'usage de matériel qu'ils destinent au déminage humanitaire.

Le présent document décrit les essais effectués dans l'air ambiant qui constituaient un élément de la contribution canadienne au IPPTC. Le principal objectif de ces essais, effectués au Centre de recherches pour la défense Suffield (CRDS), était de comprendre certains paramètres de fonctionnement de base des détecteurs dans une atmosphère contrôée de laboratoire. Six essais distincts étaient réalisés. Quatre de ces essais, à savoir ceux d'étalonnage, de dérive, de teneur en eau et de vitesse de balayage ont permis de déterminer combien la performance du détecteur est influencée par la méthode initiale de réglage et d'étalonnage, la dérive électronique, la condensation de l'eau sur la tête de détection et la vitesse à laquelle le détecteur est balayé. Les résultats ont montré que l'influence de ces facteurs sur la performance variait notablement parmi les détecteurs. L'essai de sensibilité a permis de mesurer la capacité d'un détecteur de déceler diverses mines terrestres et d'autres cibles. Les résultats ont indiqué une grande variation de la distance à laquelle la cible pouvait être détectée par les différents modèles. L'essai de profil de balayage a produit des ≪ empreintes ≫ du détecteur, qui précisent la manière dont la détectabilité d'une cible peut dépendre de son emplacement, relativement à la bobine détectrice. Contrairement aux affirmations de certains fabricants, les données obtenues de cet essai ont montré que l'empreinte du détecteur s'amenuise à mesure que la distance de la cible augmente.

Le fait qu'un détecteur soit capable de déceler des cibles dans l'air ne signifie pas toujours que ce détecteur peut déceler des cibles dans le sol, mais les résultats des essais dans l'air servent à de nombreuses fins utiles. Par exemple, ils fournissent des données sur la répétabilité et la stabilité de la performance d'un détecteur; comparent les distances de détection de diverses cibles, révélant ainsi les points faibles des détecteurs optimisés pour une cible unique; identifient les détecteurs qui n'ont pas la distance minimum de détection nécessaire pour les cibles importantes; procurent des données d'empreinte servant à déterminer des circuits de recherche et assurer ainsi la couverture voulue. Les résultats pourraient aussi servir à vérifier le cahier des charges constructeur, ce qui préviendra le choix de détecteurs manifestement inadéquats, à expliquer les résultats des essais opérationnels et à élaborer des procédés de formation et des modes d'emploi convenables. On devrait utiliser les données obtenues de ces essais conjointement avec celles des autres essais IPPTC pour choisir des détecteurs

destinés à une situation donnée.

Les futures études de ce type devraient envisager la réalisation d'essais additionnels pour déterminer combien l'état de charge de la pile, la température et l'humidité, le bruit électromagnétique ambiant et l'expérience personnelle de l'opérateur influencent la performance du détecteur.

Y. Das, J.D. Toews , K. Russell, S. Lewis. 2000. Résultats du test fait dans l'air sur détecteurs de métaux. DRES TR 2000-185. Centre de recherches pour la défense, Suffield.

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1. Introduction

1.1 Background

This document presents results of tests conducted at the Defence Research Establishment Suffield (DRES) as a part of Canadian contribution to the International Pilot Project for Technology Co-operation (IPPTC) in mine detection [1]. The participants of this project were government agencies and research institutes from Canada, the U.S.A., the U.K., the Netherlands and the European Union. Canadian participation in this project was under the auspices of the Canadian Centre for Mine Action Technologies (CCMAT) which is co-located with DRES. The goal of this pilot project was to conduct various laboratory and field tests on a number of commercial metal/mine detectors in order to provide relevant information to potential sponsors and end users of such technology to help them make informed decisions about their equipment selection and use in humanitarian demining.

The work under this pilot project was carried out in a number of phases. Phase 1 involved assessment of availability of detectors and purchase of three samples each of 29 models of handheld commercial-off-the-shelf metal detectors from a number of manufacturers who claim their products to be suitable for mine detection. In Phase 2, members of the IPPTC technical evaluation team familiarized themselves with the operations of the detectors. All the detectors were subjected to a simple entrance test to qualify for further testing under this project. Details of Phase 1 and Phase 2 work are embedded in the minutes of IPPTC meetings and in various informal notes. The aim of Phase 3 was to assess the performance of the detectors in finding mine targets buried in known soil types, and to this end tests were conducted at the HOM-2000 soil test lanes at the Physics and Electronics Laboratory of The Netherlands Organization for Applied Scientific Research (TNO-FEL) in The Hague. Details of these tests are included in [2]. Phase 4 consisted of controlled laboratory tests (referred to as the In-Air Tests) led by Canada and an ergonomic assessment of the detectors led by the U.K., both being conducted at DRES. Phase 5, led by the U.S.A., consisted of testing the detectors under field conditions in two countries with well-known landmine problems, namely, Cambodia and Croatia. Phase 6 included data analysis, preparation of reports and dissemination of gathered information. The different phases are seen as complementing each other, and technical representatives of all participants of IPPTC took part in all phases of the project.

In this report we present the results of the In-Air Tests only.

1.2 The Tests

Detailed description of the In-Air Tests including the experimental facility, equipment and procedures used are given in a related document [3]. Here we only include a brief overview of these tests for easy reference.

The concept behind the tests came from experience in testing a large number of

detectors from various manufacturers worldwide. Ideas behind these tests and other issues in evaluating performance of metal detectors are summarized in [4]. Tests conducted under the mandate of Phase 4 of the IPPTC project are only a subset of laboratory tests that could and should have been conducted if time and resources permitted. The tests conducted in a controlled laboratory environment focused on a detector's ability to detect objects in air (also referred to as its in-air sensitivity) and assessed how this sensitivity is affected by various parameters found in real-world conditions. While a detector's ability to detect objects in air does not directly indicate its ability to detect objects buried in the ground, such controlled tests are very useful in comparing certain basic performance factors. As well, such tests provide information needed to understand a detector's performance in the field. The following is a list, with brief description, of the tests conducted.

Calibration Test This test determines the repeatability of the initial set-up or "calibration" procedure of a detector. The results give an indication of the expected variability in performance in practice as a detector is set up by different operators or by the same operator on different occasions.

Drift Test This test determines the extent of the change in sensitivity of a detector over a half-hour period following an initial warm-up. The results show whether and by how much a detector's performance will deteriorate (or vary) over a short time period.

Sweep Speed Test This test determines how the sensitivity of a detector changes as a function of the speed with which the detector head is swept over a target. The results show what effect the speed with which an operator moves a detector have on its sensitivity.

Moisture Test This test determines the extent to which moisture on the sensor head affects the sensitivity of a detector. The results indicate how much a detector's sensitivity will change if the search head comes in contact with water, such as when operating in dew-covered vegetation or in light rain.

Sensitivity Test This test determines a detector's ability to detect a variety of targets. Some detectors are optimized for specific targets, often the test piece supplied by the manufacturer. The results of this test establish a detector's ability to detect other targets of interest to the user.

Scan Profile Test This test determines the scan profile (also called "footprint") of a detector, that is, the variation of sensitivity as a function of a target's location with respect to the detector head. The results give an indication of how closely to space consecutive sweeps to ensure desired coverage.

The above In-Air Tests can be divided into three categories.

(a) These tests are aimed at measuring how much variation in sensitivity is to be expected due to various factors inherent in field use. The Calibration, Drift, Moisture and Sweep-Speed Tests belong to this group.

(b) This category includes the Sensitivity Test, which measures the ability of a detector to detect a variety of targets of interest.

(c) The final category consists of the Scan Profile Test, which determines the variation of response produced by a small target as a function of its location with respect to the detector head.

If more time and resources were available, three additional tests could have been conducted. These are:

(1) **power consumption** and any **effect of battery state** on detector performance;

(2) **effect of temperature and humidity** on detector performance; and

(3) **effect of ambient electromagnetic noise** on detector performance.

Most detectors have a low battery indicator which is meant to assure a given performance as long as the battery voltage is over a certain value. As well, some preliminary tests with a very commonly used detector indicated that the battery state issue is not critical enough to warrant testing at this time at the cost of other tests. However, the effects **(2)** and **(3)** are deemed to be important in humanitarian demining and the fact that they were not assessed must be viewed as one of **the deficiencies of the current project.**

1.3 Experimental Facility

All in-air testing at DRES was conducted in the Foam Dome (Figure 1), an all weather foam building which due to its non-conductive, non-magnetic construction can be used to make very low noise magnetic and low frequency electromagnetic measurements.

An apparatus consisting of a scanner and a target holder, both built of non-metallic materials, were specially developed to provide accurate mechanical control over sweep speed and target location. Various views of this setup are shown in Figures 2 to 6. Further details of the device will be the subject of future DRES reports. Briefly speaking, a barrel cam, suitable gears and other mechanisms are used to convert the rotational motion of an electric motor (or other suitable driving mechanism) into a side-to-side linear motion of the detector head which is attached to a mount moving on the barrel cam. The scanner can be set up to automatically move the detector head over

a 1 m × 1 m area (area or 2-D scan mode) in a raster scan fashion or to repeatedly move the head over a chosen line (line or 1-D scan mode). In all our tests except the Scan Profile test, the scanner was used in the 1-D mode. The sweep speed of the sensor head, which is derived from an optical encoder mounted on the long shaft driven by the electric motor, can be varied in the range 0 to 1 m/s. The length of the drive shaft was chosen to ensure that the electric motor, which was selected for its low EMI, was far enough away and did not adversely affect the metal detector.

1.4 The Data Acquisition System

Essentially all commercial metal detectors have an audio output through a headphone or a speaker. An operator listens for a change in the audio output of a detector to decide if a target is present. Such a decision depends critically on an individual's hearing, judgement, attentiveness, experience and so on, particularly when the change in audio signal is small, which is the case when one tries to determine the maximum distance at which a target is detectable. Because of this potentially significant dependence of the results on a particular operator conducting a test, a decision was made early in the project to digitally record the audio signals from the detectors during the tests. Such recorded signal, in addition to serving as a record of the tests, could be subsequently processed by a suitable computer algorithm or be analyzed by any number of human operators, in order to arrive at decisions free of operator bias.

The quality of the headphone used in a detector affects its audio signal. Idealy, in order to preserve the sound of a detector, the acoustic output directly from its headphone should be recorded. A Georg Neumann KU100 dummy head designed for such an application was acquired and tested. The dummy head is a replica of the human head with a microphone and preamplifier built into each ear. Although this method could, in principle, be used, it was not possible to isolate, to a satisfactory degree, the various extraneous sounds (e.g., scanner noise, vehicles driving by, helicopters near by, and so on) that were inevitably present at the DRES test site. Earlier, the test site at TNO-FEL had also been found to be unsuitable for direct acoustic recording. To circumvent the problems of direct acoustic recording, it was decided to record the electrical signal that drives the headphone. This necessitated minor modifications to the headphone cable and development of some additional electronics so that the electrical signal could be properly digitized. Modification to the headphones as well as construction of additional electronics were done by TNO-FEL and are described in detail in [2].

A PC-compatible computer with a 16 bit analog-to-digital converter board was used as the data acquisition hardware. A suitable data acquisition software program was developed by DRES using LabVIEW® (a graphical software development tool). The program was slightly modified by TNO-FEL to add an instant replay feature [2]. The hardware/software combination provided a very user-friendly way of collecting and storing on disk digitized audio output of the detector as a function of position of the search head.

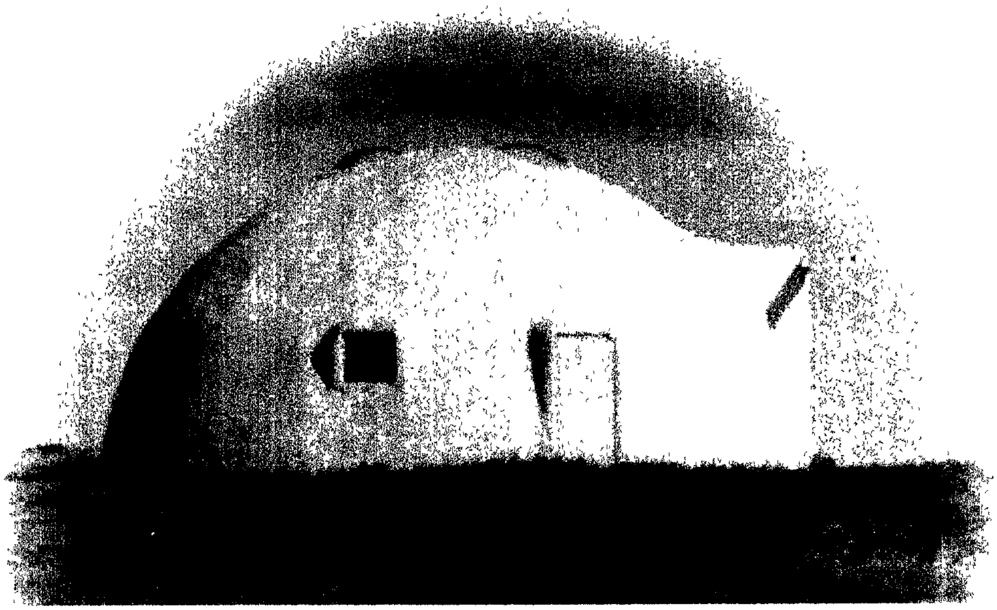

Figure 1: *The Non-metallic Building (Foam Dome)*

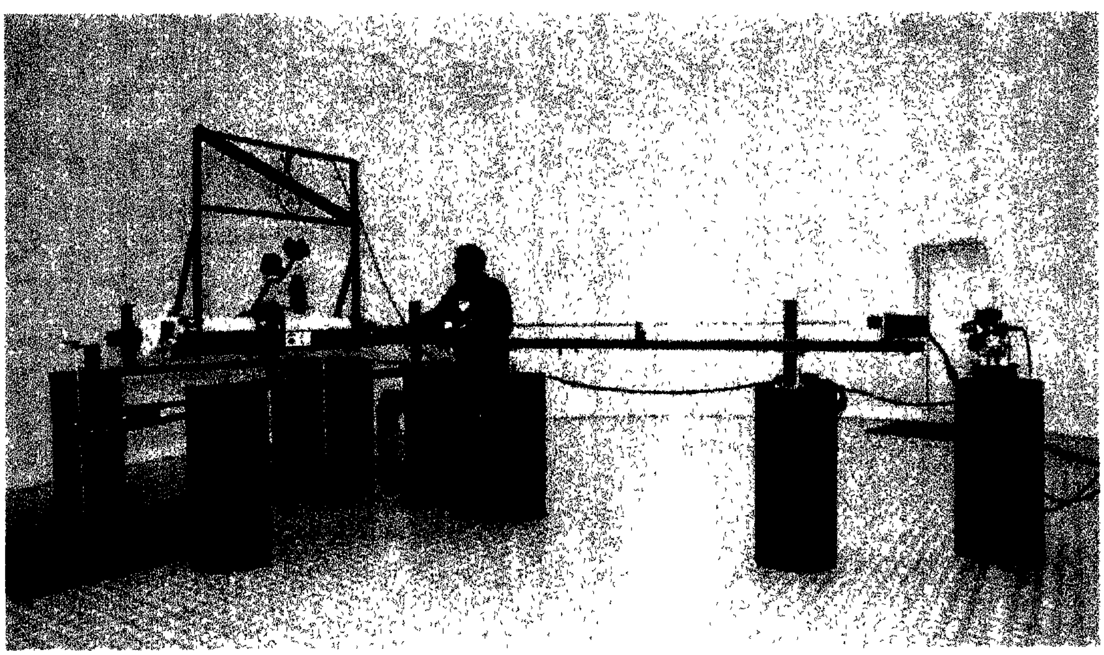

Figure 2: *An Overall View of the Scanning Apparatus*

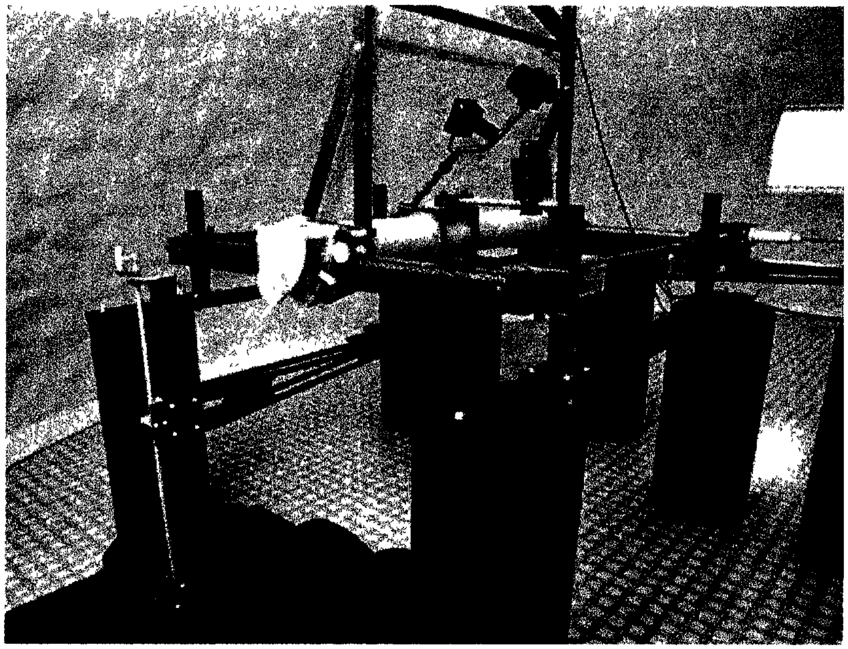

Figure 3: *Close-up Side View of the Scanner and the Target Holder*

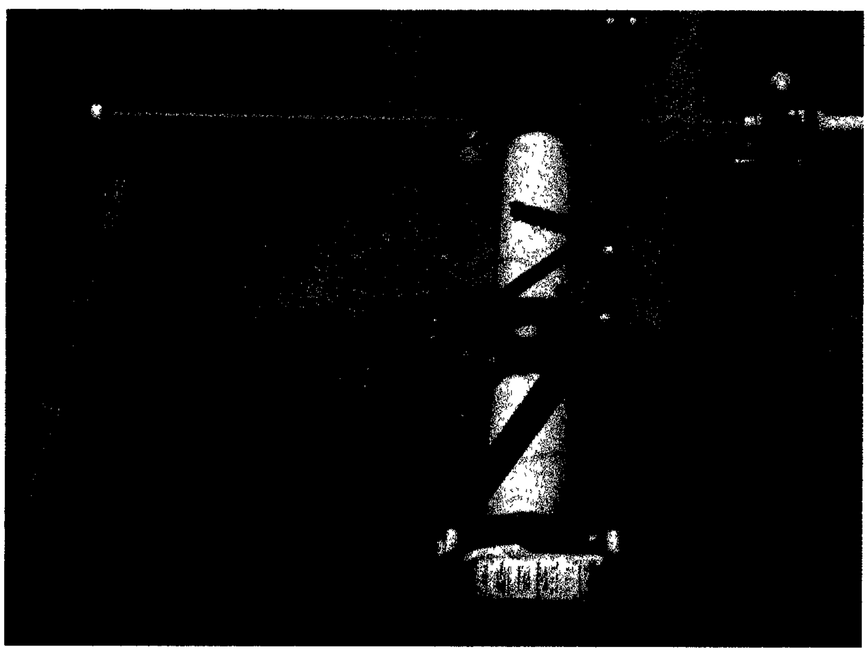

Figure 4: *Close-up Top View of the Scanner*

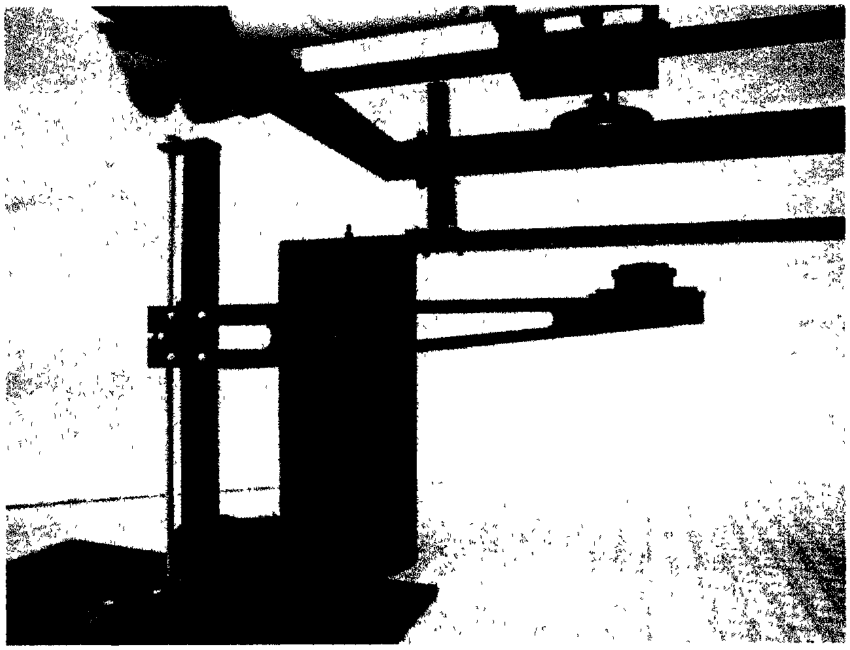

Figure 5: *Close-up View of the Target Holder*

Figure 6: *Close-up View of the Operator Work Station*

1.5 General Procedure

One basic process inherent in almost all the In-Air Tests is the determination of the maximum distance that a target can be detected from the sensor head. This is defined as the "maximum detection distance" and taken as a measure of sensitivity of the detector.

In manually conducted tests, an operator listens to the audio output of the detector while passing a target by hand under the detector at a progressively increasing distance, until the operator judges the target to be "not detected". This process, although subjective and its results vary somewhat between operators, is very quick and gives practical and useful data. However it is rather difficult to recreate this process using only machines, mainly because the human real-time decision making and feedback is not used and some sort of computer processing (to remove the bias of an operator) needs to be employed (likely offline). Hence there is a need to store detector output corresponding to a target at a number of distances. To this end, targets were placed on a specially designed device which could be used to precisely move a target up and down (Figure 5) to control target distance. To keep the data volume at a reasonable level, it was decided to collect detector output data only at five discrete target distances which bracket an operator-determined maximum detection distance, d_{op}. The operator determined d_{op} by listening to detector output as a second operator adjusted the target distance based on the feedback from the former. The five discrete distances chosen were $d_{op} - 4$ cm, $d_{op} - 2$ cm, d_{op}, $d_{op} + 2$ cm and $d_{op} + 4$ cm.

The original intent was to follow the above procedure for all the tests. However, at the IPPTC project meeting at DRES held during 19-20 October 1999, it was agreed that to follow such a process for all the planned tests would be very time consuming and would yield an enormous volume of data. As well, a suitable automatic data processing technique had not been identified and only proposed post processing of collected data was through playing them back to human operators (possibly to a number of them to reduce bias). Ways to reduce time required for the tests were discussed and it was agreed that some of the tests could be done without storing data for post processing but relying instead on the operator-determined maximum detection distance. For tests where the relative effect of a parameter on the performance of a given detector were to be determined, undue bias would not be introduced by having an operator make the determination of maximum detection distance. An example of such a test would be the moisture test where the purpose is to determine the **change** in sensitivity of a detector as a function of the amount of water sprayed on the search head. The absolute value of the maximum detection distance is not as important in this case as the relative change in this distance caused by moisture. Thus as long as the same operator is used for the entire moisture test for a detector, operator bias should not unacceptably affect the information being sought from this test. Other tests where this procedure was used are Calibration and Drift. Since no automatic processing algorithm had been developed at the time of writing, for the purposes of this report, operator-determined results (d_{op}) are also used for the Sensitivity and Sweep Speed Tests although detector outputs were recorded during these tests. For the Scan Profile Test, digitally recorded data were used

to generate the detector foot prints.

Because of mechanical limitations early in the tests, maximum detection distance of some detector/target combinations could not be achieved. **An arrow will be placed on top of the chart bar(s) in Figures to indicate where this occured. In Tables, this situation will be indicated by using numbers in bold. Care must be excercised in interpreting these detection distances.**

1.6 Targets

The selection of a set of targets, even for a relatively well-understood sensor like a metal detector, is not simple [4]; this is in part because various interested parties hold diverse opinions as to what the results of a test and evaluation procedure is supposed to establish. Some would like the results of a test to indicate with absolute certainty how well a given detector will perform against all landmines. Others will argue that a certain chosen target does not represent any landmine. Although it is possible to classify the hundreds of different types of existing mines into a few generic categories [5] such as antipersonnel (AP) blast, AP fragmentation, antitank (AT) blast, and so on, it will be very difficult to obtain agreement on a small selection of landmines to represent the entire population of existing mines. The situation is made worse by the fact that live mines of the desired types are not readily available and by the safety issues involved in using live mines. As well, information on exact metal content of various mines is not readily available making the task of reproducing the metal components in a mock-up mine difficult.

For this project, targets were selected based on an analysis of most commonly occurring antipersonnel mines in countries with a landmine problem. A total of 11 target types were used for these trials. Of these, seven were inert mines and mine-like objects and the remaining four were metal test objects. The mine targets were supplied by the US with technical support from TNO-FEL, MTM (a private Dutch company[1]) and C. King Associates in the UK. It was assumed that the inert mines and mine-like objects were prepared in such a way that the dimensions, the type of metal, the relative positions and orientations of all metal components were the same as in the corresponding mine in the armed state. So, for all practical purposes these targets should behave the same way as the corresponding real mines as far as metal detectors were concerned. Description of the real mines can be found in many places including [5]. A brief description of the targets, taken from the TNO-FEL report [2], follows. The IPPTC designation for the actual item (out of a number of available copies of each target type) used in our tests is shown in paranthesis beside the name of the mine or the test piece.

1.6.1 Inert mines and mine-like objects

PMN (Z-2-11) Original Russian **PMN** mines with replica detonators made by C. King Associates. Fuse mechanism was put

[1] Munitie Technologische Modellen, Rijshornstraat 73, 1435 HG Rijsenhout, The Netherlands

in armed position and blocked to prevent activation. Targets were filled with an imitation explosive charge (bitumen-covered sulphur) by MTM.

PMN-2 (Z-3-02) Original Russian **PMN-2** mines with original aluminium detonators (which had been inerted) and booster spring. Fuse mechanism was put in armed position and blocked to prevent activation. Filled with an imitation explosive charge (silicone rubber RTV3110, Dow Corning) by TNO-FEL.

PMA-2 (Z-4-01) Original Yugoslavian **PMA-2** mines with original aluminium detonators which had been inerted. Detonator capsule was in armed position. Filled with an imitation explosive charge (silicone rubber RTV3110, Dow Corning) by TNO-FEL.

PMA-3 (Z-1-01) Original Yugoslavian **PMA-3** mines, with replica PVC detonators and fuse assemblies fabricated by C. King Associates. There was no imitation explosive charge filling and were used with the metal spring band in place.

Type 72A (Z-5-01) Original Chinese **Type 72** antipersonnel mines. Fuse mechanism was in armed and blocked position. Replica aluminium detonators were used. Filled with an imitation explosive charge (silicone rubber RTV3110, Dow Corning) by TNO-FEL. **In the various IPPTC reports, this target may be interchangeably referred to as Type 72A or simply Type 72**

R2M2 (Z-6-01) Surrogate mines fabricated by C. King Associates. Consist of complete replica fuse assemblies in waterproof housings of the correct height. Filled with an imitation explosive charge (silicone rubber RTV3110, Dow Corning) and foam by TNO-FEL.

PMD-6 (Z-0-11) Exact replicas of **PMD-6** mines fabricated by MTM, complete with original RO-1 detonator. Fuse mechanism was put in armed position and blocked to prevent activation. Filled with an imitation explosive charge (silicone rubber RTV3110, Dow Corning) by TNO-FEL.

1.6.2 Metal test pieces

G_0 (Z-7-01) A target simulant [6], **G_0** is a very small copper tube, 12.7 mm (0.5 inch) long, 3.175 mm (0.125 inch) in

diameter and with a wall thickness of 0.381 mm (0.015 inch). Its mass is 0.393 g. Each $\mathbf{G_0}$ test object is placed in a mine simulant shell with a diameter of 57 mm.

$\mathbf{I_0}$ (Z-8-01)	A target simulant [6], $\mathbf{I_0}$ is a small aluminium tube, 12.7 mm (0.5 inch) long, 4.75 mm (0.187 inch) in diameter and with a wall thickness of 0.381 mm (0.015 inch). Its mass is 0.172 g. Each $\mathbf{I_0}$ test object is placed in a mine simulant shell with a diameter of 88 mm.
$\mathbf{M_0}$ (Z-10-01)	A target simulant [6], $\mathbf{M_0}$ is a large aluminium tube, 38.1 mm (1.5 inch) long, 6.35 mm (0.25 inch) in diameter and with a wall thickness of 0.381 mm (0.015 inch). Its mass is 0.66 g. Each $\mathbf{M_0}$ test object is glued to a PVC holder (dimensions:42X42X8 mm). **This target was used in all the In-Air Tests and is often referred to simply as the Al Tube in the test logbooks and elsewhere.**
STP (STP)	This is the test pin that comes with the Schiebel AN19/2 mine detector. This target was included in the In-Air Tests so that one could compare certain results from these tests with those of tests conducted previously by DRES and others.

1.7 Detectors

The detectors tested are listed below. The left column shows the designation assigned by IPPTC to each detector while the right column includes the manufacturer's model number. The three samples of each detector model will be referred to by the IPPTC designantion followed by a -1,-2 or -3 respectively. Thus the three Minelab F1A4-CMAC detectors will be referred to as **MICM-1, MICM-2, MICM-3**.The reader should consult manufacturers' instruction booklets for technical information on these detectors.

AD25	Adams Electronics AD2500
AD26	Adams Electronics AD2600
EB53	Ebinger EBEX 535
EB42	Ebinger EBEX 420 GC[2]

[2] All three samples had failed. Only one working unit, made of parts from the three, was available for testing.

FI12	Fisher Research 1235X
FIIM	Fisher Research Impulse 10.5"
FIXB	Fisher Research 1266 XB 8"
FOMI	FOERSTER Minex 2FD 4.400.01
GIAT	GIAT Model F1 (DHPM-1A)
GUA2a	Guartel MD2000 (round search head)
GUA2b	Guartel MD2000 (long probe)
GUA2c	Guartel MD2000 (short probe)
GUA4	Guartel MD4
GUA8a	Guartel MD8 (round search head)
GUA8b	Guartel MD8 (oval search head)[3]
GUA8c	Guartel MD8 (probe)
LGPR	LG Precision PRS 17K
MICM	Minelab F1A4-CMAC
MIMI	Minelab F1A4-MIM
PRMA	Pro Scan Mark 2 VLF
REMI	Reutech Midas PIMD
SCAN	Schiebel AN-19/2
SCAT	Schiebel ATMID
SCMI	Schiebel MIMID
VA16	Vallon ML1620C
VAVMa	Vallon VMH2
WHAF	White's AF-108
WHSP	White's Spectrum XLT
WH59	White's DI-PRO 5900

[3]This search head turned out to be a preproduction model with reliability problems. Only one unit was tested.

2. Calibration Test

For consistent results and safety, operators should avoid using detectors whose performance changes significantly each time the detector is adjusted or set up for use. It is expected that detectors where the setting up process is digital and the operator simply pushes a button to get the detector ready for search, consecutive settings should essentially produce the same results. On the other hand, for detectors where the calibration is performed by turning a knob which may control a potentiometer for example, one could expect some variation even when all other variables are the same and the same operator performs the test. This variation could be significant if the adjustment method (the physical construction of the potentiometer and the knob for example) has built-in nonlinearity and backlash.

The purpose of this test, as mentioned earlier, was to determine the repeatability of the initial set-up of a detector. The test measured the maximum detection distance, using a selected target ($\mathbf{M_0}$ in vertical orientation), for five consecutive set-ups of a detector after an initial warm up period. The same operator performed the five set-ups and measurements on a given detector unit. Two samples of each detector model were tested, but not necessarily by the same operator.

The results are shown in Figure 7 and in Tables 1 and 2. Figure 7 graphically shows the spread of maximum detection distance for the five consecutive set-ups, while the raw data are presented in Table 1 and Table 2. The orange bars in Figure 7, and Table 1 present results for the less sensitive of the two samples of a detector model tested. The blue bars and Table 2 present data for the other sample.

There was a wide range of variation among the detectors. The sensitivity of some detectors remained essentially constant. In others it changed resulting in differences of up to 10 cm in the maximum detection distance, which represents a significant variation. As with the other category (a) tests, in assessing the implication of this data, one should not only consider the variability in detection distance but also the value of the detection distance itself. From the standpoint of this test, the best detector is one that detects the target at the greatest distance and has no variation in that distance from one set-up to another. A detector that has very little variation but detects the target only at a short distance is of little use in mine detection. The user has to be careful in using detectors that have high or adequate sensitivity but also display large variation from one set-up to another. If using such detectors, the user should be aware of and account for significant variation in performance in the field due to lack of repeatability of the set-up procedure. One should prefer a detector which has acceptable minimum detection distance combined with a small variation.

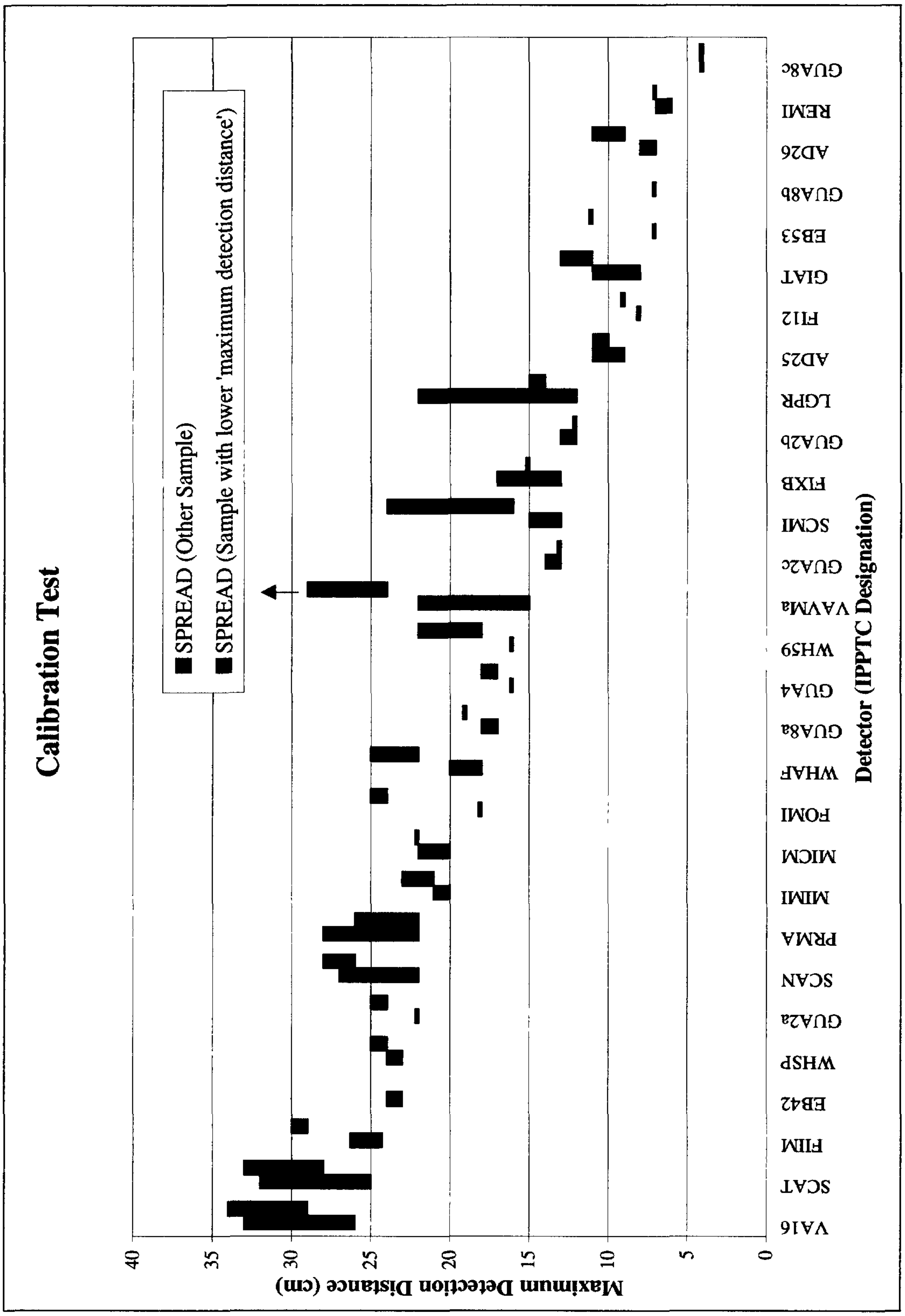

Figure 7: *Variation of maximum detection distance for five consecutive set-ups. Arrow indicates "greater than" (Section 1.5)*

***Table 1:** Maximum detection distance for five consecutive set-ups (the less sensitive sample)*

Sample	Maximum detection distance in air - cm.						
	1st	2nd	3rd	4th	5th	Minimum	Spread
VA16-3	28	28	26	27	33	26	7
SCAT-2	32	31	32	25	32	25	7
FIIM-1	25	26	24	25	24	24	2
EB42-2	23	23	24	24	24	23	1
WHSP-2	23	23	24	23	23	23	1
GUA2a-1	22	22	22	22	22	22	0
SCAN-2	24	22	24	24	27	22	5
PRMA-1	22	27	28	25	26	22	6
MIMI-2	21	20	21	21	21	20	1
MICM-2	22	21	22	21	20	20	2
FOMI-2	18	18	18	18	18	18	0
WHAF-1	18	20	19	19	19	18	2
GUA8a-1	18	17	17	18	18	17	1
GUA4-2	16	16	16	16	16	16	0
WH59-2	16	16	16	16	16	16	0
VAVMa-2	15	22	22	22	22	15	7
GUA2c-1	14	13	13	13	13	13	1
SCMI-2	15	13	14	14	14	13	2
FIXB-1	16	17	14	13	13	13	4
GUA2b-1	12	12	13	12	13	12	1
LGPR-2	16	20	18	22	12	12	10
AD25-1	9	9	9	10	11	9	2
FI12-1	8	8	8	8	8	8	0
GIAT-3	8	9	10	11	10	8	3
EB53-2	7	7	7	7	7	7	0
GUA8b-1	7	7	7	7	7	7	0
AD26-1	7	8	8	7	8	7	1
REMI-1	6	7	6	7	7	6	1
GUA8c-1	4	4	4	4	4	4	0

Table 2: *Maximum detection distance for five consecutive set-ups (the more sensitive sample). Only one working sample each of EB42 and GUA8b was available for testing (Section 1.7). A number in bold indicates a distance greater than that shown (Section 1.5).*

Sample	Maximum detection distance in air - cm.						
	1st	2nd	3rd	4th	5th	Minimum	Spread
VA16-2	34	30	31	29	32	29	5
SCAT-1	28	33	28	30	32	28	5
FIIM-2	29	30	29	30	30	29	1
EB42-*	NO DATA						
WHSP-1	25	25	25	25	24	24	1
GUA2a-2	24	24	25	25	25	24	1
SCAN-1	28	26	27	28	28	26	2
PRMA-2	22	25	23	26	26	22	4
MIMI-1	23	22	21	21	22	21	2
MICM-1	22	22	22	22	22	22	0
FOMI-1	24	24	24	25	24	24	1
WHAF-2	25	24	23	22	23	22	3
GUA8a-2	19	19	19	19	19	19	0
GUA4-1	17	17	18	17	18	17	1
WH59-1	18	21	19	22	20	18	4
VAVMa-1	26	24	26	**29**	27	24	5
GUA2c-2	13	13	13	13	13	13	0
SCMI-1	24	16	19	19	18	16	8
FIXB-2	15	15	15	15	15	15	0
GUA2b-2	12	12	12	12	12	12	0
LGPR-1	15	15	15	14	15	14	1
AD25-2	11	10	11	10	10	10	1
FI12-2	9	9	9	9	9	9	0
GIAT-2	12	13	12	11	12	11	2
EB53-1	11	11	11	11	11	11	0
GUA8b-*	NO DATA						
AD26-2	9	10	11	10	11	9	2
REMI-2	7	7	7	7	7	7	0
GUA8c-2	4	4	4	4	4	4	0

3. Drift Test

A reduction in sensitivity with time without warning to the operator could be potentially dangerous. One needs to know if a detector maintains its sensitivity without readjustment by the operator over a desired period of time. Some users had previously indicated that a detector must maintain its sensitivity within acceptable limits over at least a 30-minute period in order to avoid the need for frequent readjustment and to gain operator confidence. Accordingly, the purpose of this test was to determine the extent of the change in the sensitivity of a detector over a 30-minute period.

After an initial warm-up period of three minutes (in the absence of a manufacturer's requirement for longer periods), the detector was set up according to the manufacturer's recommended procedures and the maximum detection distance for the $\mathbf{M_0}$ target, in vertical orientation, was measured. This measurement was repeated, without readjusting the detector, every three minutes over a period of about 30 minutes. The temperature of the laboratory was essentially constant during the tests for all detectors. Two samples of each detector model were tested, but not necessarily by the same operator.

The results are shown in Figure 8 and in Tables 3 and 4. Figure 8 shows the total variation in maximum detection distance for all the detectors over a 30 minute period. The raw data representing maximum detection distance measured every three minutes are shown in Tables 3 and 4. The orange bars in Figure 8, and Table 3 present results for the less sensitive of the two samples of a detector model tested. The blue bars and Table 4 present data for the other sample.

There was a wide range of variation in the drift performance among the detectors. In some detectors the sensitivity remained essentially constant while in others the maximum distance changed by almost 10 cm which represents a significant variation. As is the case with the other category (a) tests, in interpreting the results of this test, one should consider both the detection distance as well as its variation. One must avoid using detectors whose performance changes significantly due to short term drift. One should prefer a detector which has acceptable minimum detection distance combined with a small variation over time. Detectors with excessive drift would seem to behave erratically in the field and should be avoided. It is also important to know if the sensitivity decreases with time. However, any trend suggested by data in Tables 3 and 4 must be confirmed by repeating the test a number of times before accepting it. It should be emphasized that the effect of varying temperature, expected in the field, on drift was not measured in this test.

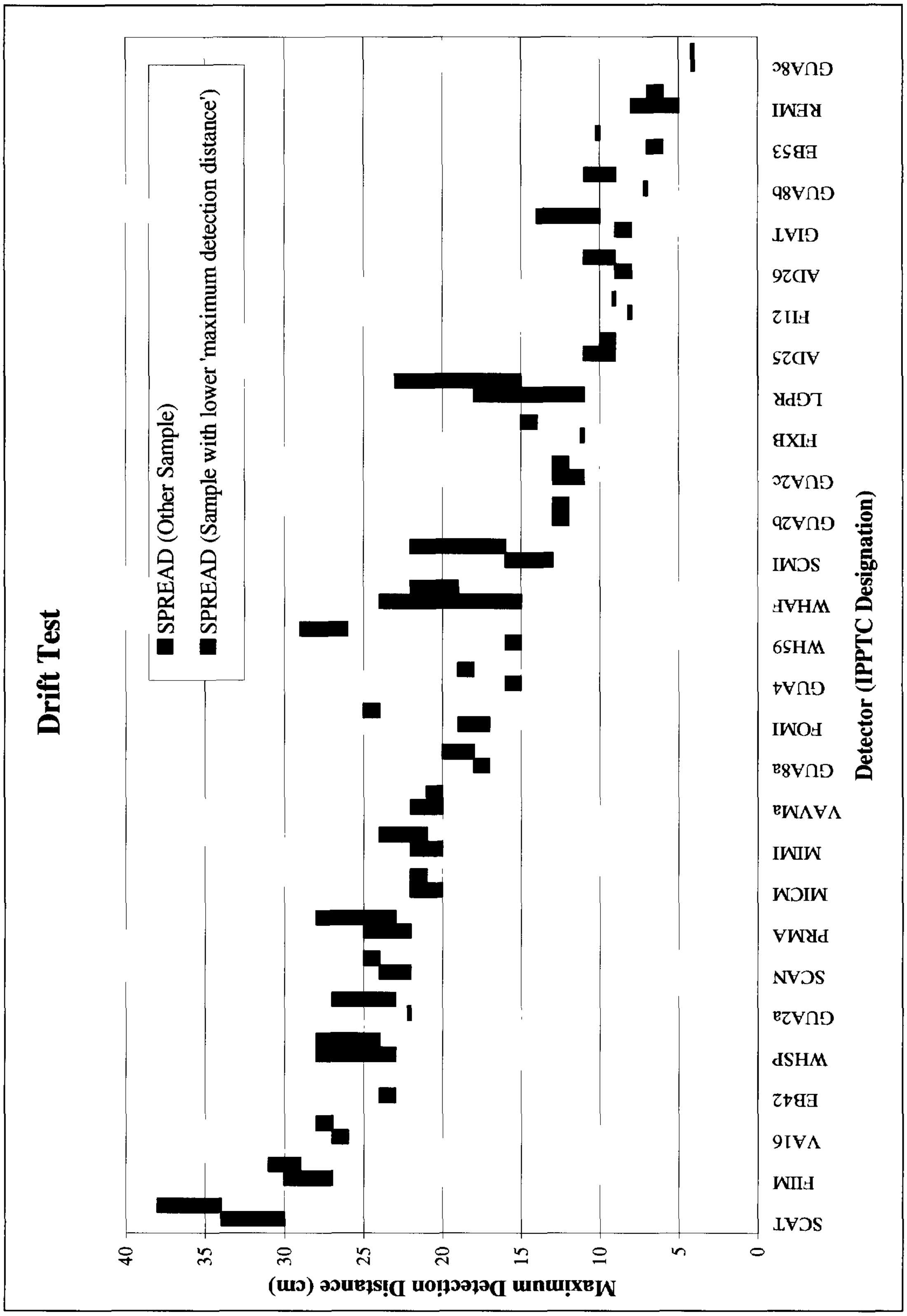

Figure 8: *Range of maximum detection distance over the first 30 minutes after initial warm-up for all detectors.*

Table 3: Maximum detection distance over the first 30 minutes after initial warm-up (data for the less sensitive sample).

Sample	Maximum detection distance in air - cm.											
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	Minimum	Spread
SCAT-2	34	32	31	30	30	31	30	31	30	30	30	4
FIIM-1	28		29	28	28	29	28	27	28	30	27	3
VA16-2	26	27	27	27	27	27	27	26	27	27	26	1
EB42-2	24	24	23	24	23	23	23	23	23	24	23	1
WHSP-2	23	24	24	23	27	27	26	26	28	23	23	5
GUA2a-1	22	22	22	22	22	22	22	22	22	22	22	0
SCAN-2	22	23	23	23	23	24	23	24	23	22	22	2
PRMA-2	24	23	22	22	22	24	25	25	25	25	22	3
MICM-2	21	20	21	20	22	21	22	21	20	22	20	2
MIMI-2	21	21	21	22	22	21	21	21	20	20	20	2
VAVMa-2	20	21	20	21	20	20	20	21	22	22	20	2
GUA8a-1	18	18	17	17	17	18	18	18	17	18	17	1
FOMI-2	19	19	19	18	18	18	18	18	18	17	17	2
GUA4-2	16	15	16	16	16	16	16	16	16	16	15	1
WH59-2	15	15	15	16	16	16	16	16	16	16	15	1
WHAF-2	22	22	24	23	22	22	22	20	16	15	15	9
SCMI-2	16	15	14	14	13	13	13	13	13	13	13	3
GUA2b-2	12	12	12	13	12	13	12	12	12	12	12	1
GUA2C-1	12	13	13	13	13	13	12	13	13	13	12	1
FIXB-1	11	11	11	11	11	11	11	11	11	11	11	0
LGPR-1	14	16	15	18	12	14	11	12	11	11	11	7
AD25-2	11	9	11	11	10	10	9	9	9	10	9	2
FI12-1	8	8	8	8	8	8	8	8	8	8	8	0
AD26-1	9	8	9	8	8	9	9	9	9	9	8	1
GIAT-1	9	8	9	8	8	9	9	8	9	9	8	1
GUA8b-1	7	7	7	7	7	7	7	7	7	7	7	0
EB53-2	6	7	7	7	7	7	7	7	7	7	6	1
REMI-1	8	6	7	5	8	8	7	7	7	7	5	3
GUA8c-2	4	4	4	4	4	4	4	4	4	4	4	0

Table 4: *Maximum detection distance over the first 30 minutes after warm-up (data for the more sensitive of the two samples tested). Only one working sample each of EB42 and GUA8b was available for testing (Section 1.7).*

Sample	Maximum detection distance in air - cm.											
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	Minimum	Spread
SCAT-1	37	38	38	35	37	36	34	36	35	38	34	4
FIIM-2	29	29	29	29	29	31	30	30	29	30	29	2
VA16-3	28	28	28	27	28	27	28	28	27	28	27	1
EB42-*	NO DATA											
WHSP-1	25	24	28	25	26	28	28	26	25	25	24	4
GUA2a-2	27	26	24	24	25	23	26	25	25	26	23	4
SCAN-1	24	25	25	25	25	25	24	25	25	25	24	1
PRMA-1	26	24	23	26	28	26	25	26	25	27	23	5
MICM-1	21	21	21	21	21	22	22	21	22	22	21	1
MIMI-1	22	24	21	22	23	22	22	22	23	22	21	3
VAVMa-1	20	20	20	20	20	20	20	20	20	21	20	1
GUA8a-2	20	19	20	19	19	19	19	18	18	18	18	2
FOMI-1	25	25	25	24	25	25	24	25	24	24	24	1
GUA4-1	18	18	18	18	18	19	19	18	18	18	18	1
WH59-1	27	26	27	29	28	28	28	28	28	28	26	3
WHAF-1	20	20	19	21	22	22	21	20	21	20	19	3
SCMI-1	16	18	17	18	22	20	21	22	20	19	16	6
GUA2b-1	13	12	13	13	13	13	13	13	13	13	12	1
GUA2c-2	13	11	11	11	11	11	11	11	11	11	11	2
FIXB-2	15	15	15	15	14	14	14	14	14	14	14	1
LGPR-2	15	17	18	18	18	19	23		15	16	15	8
AD25-1	10	10	10	10	10	10	9	9	9	9	9	1
FI12-2	9	9	9	9	9	9	9	9	9	9	9	0
AD26-2	10	10	10	11	10	9	10	9	9	9	9	2
GIAT-2	13	12	12	12	11	10	11	13	14	13	10	4
GUA8b-*	NO DATA											
EB53-1	10	10	10	10	10	10	10	10	10	10	10	0
REMI-2	7	7	7	7	6	7	7	7	7	7	6	1
GUA8c-1	4	4	4	4	4	4	4	4	4	4	4	0

4. Sweep Speed Test

The speed at which a detector head is swept over a target has an effect on the distance at which a target is detected. Dependence of sensitivity on sweep speed is determined by the electronic coupling and filtering employed in the design of a particular detector.

A reduction in sensitivity due to a change in speed could be potentially dangerous if the operator is not aware of it. The purpose of this test was to determine how the sensitivity changes as a function of the speed with which the detector head is swept. The test measured the maximum detection distance for the M_0 target, in vertical orientation, for sweep speeds varying from 0.12 to 1 m/s. Only one sample of each detector was tested.

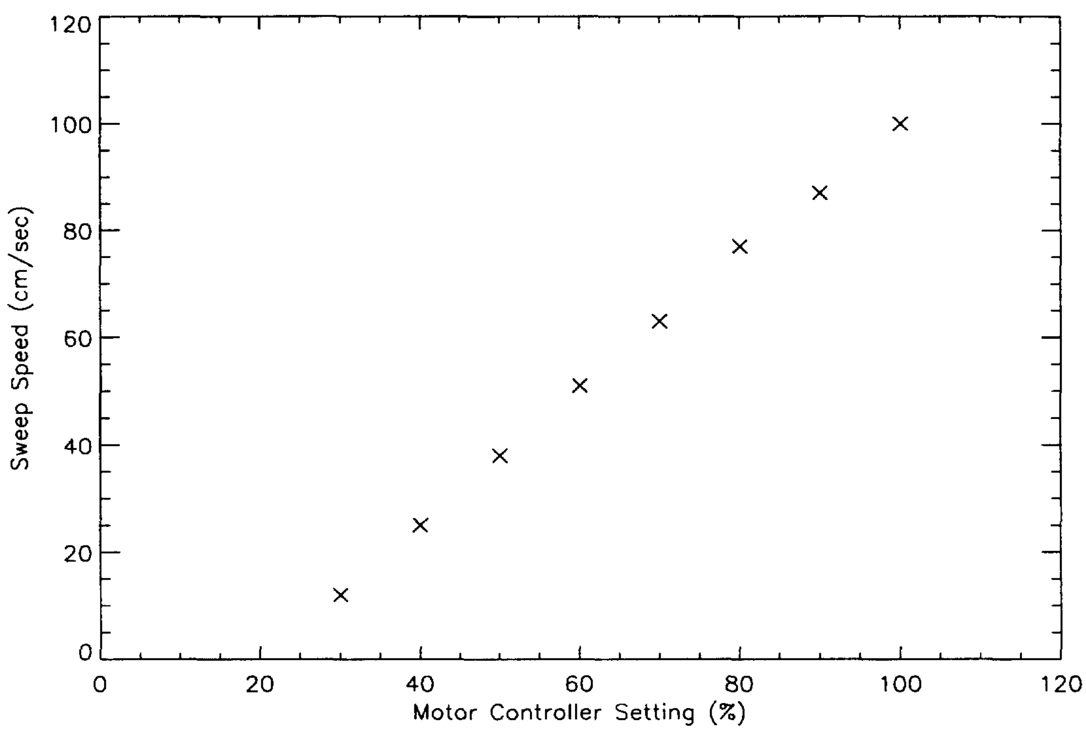

***Figure 9:** Relationship between sweep speed and percent setting on motor controller*

The sweep speed of the detector head was varied by controlling the speed of the electric motor driving the nonmetallic scanner as described in [3]. The controller of the motor had speeds indicated only as a % and in our set-up 100% nominally corresponded to a head speed of 1 m/s. The relationship between the % indications on the controller and the actual head speed was not strictly linear. An initial calibration was done to relate % setting on the motor controller to the speed of the detector; the results are shown in Figure 9. For convenience, we may at times use the % numbers to refer to the speeds. The Phase 3 tests at the HOM-2000 soil lanes at TNO-FEL in the Netherlands [2] were all conducted at a sweep speed of 0.18 m/s. This speed falls between 30 % and 40 %

speed setting in our case. All In-Air Tests except the Sweep Speed Test were performed only at 40 % speed which corresponds to 0.25 m/s. The slight difference in the speeds used for In-Soil and In-Air Tests should not hinder planned consistency checks between results from the two tests.

Figure 10 shows the total variation in maximum detection distance for all the detectors over the sweep speed range of 30 % to 100 %. The details of this variation as a function of sweep speed for each detector are shown in Figures 11-16.

There was a wide range of variation in sensitivity as a function of sweep speed among the detectors. In some detectors the sensitivity remained essentially constant while in others the maximum distance changed by as much as 10 cm which represents a significant variation. In some detectors sensitivity decreased as sweep speed increased while in others sensitivity increased with speed. In still others, sensitivity initially increased then decreased as the speed increased. End users should be made aware of this behaviour whenever such detectors are employed, so that they can adjust their training and operating procedure. From the standpoint of this test, one should prefer a detector which has acceptable minimum detection distance for the targets of interest combined with a small variation with sweep speed. Detectors with excessive variation in sensitivity with speed would seem to behave erratically in the field if a reasonably constant sweep speed can not be maintained.

Although this aspect was not thoroughly tested, it should be noted that some detectors would not detect targets when stationary. The user should make a particular point of knowing if this is the case for a chosen detector in order to develop a proper operating procedure.

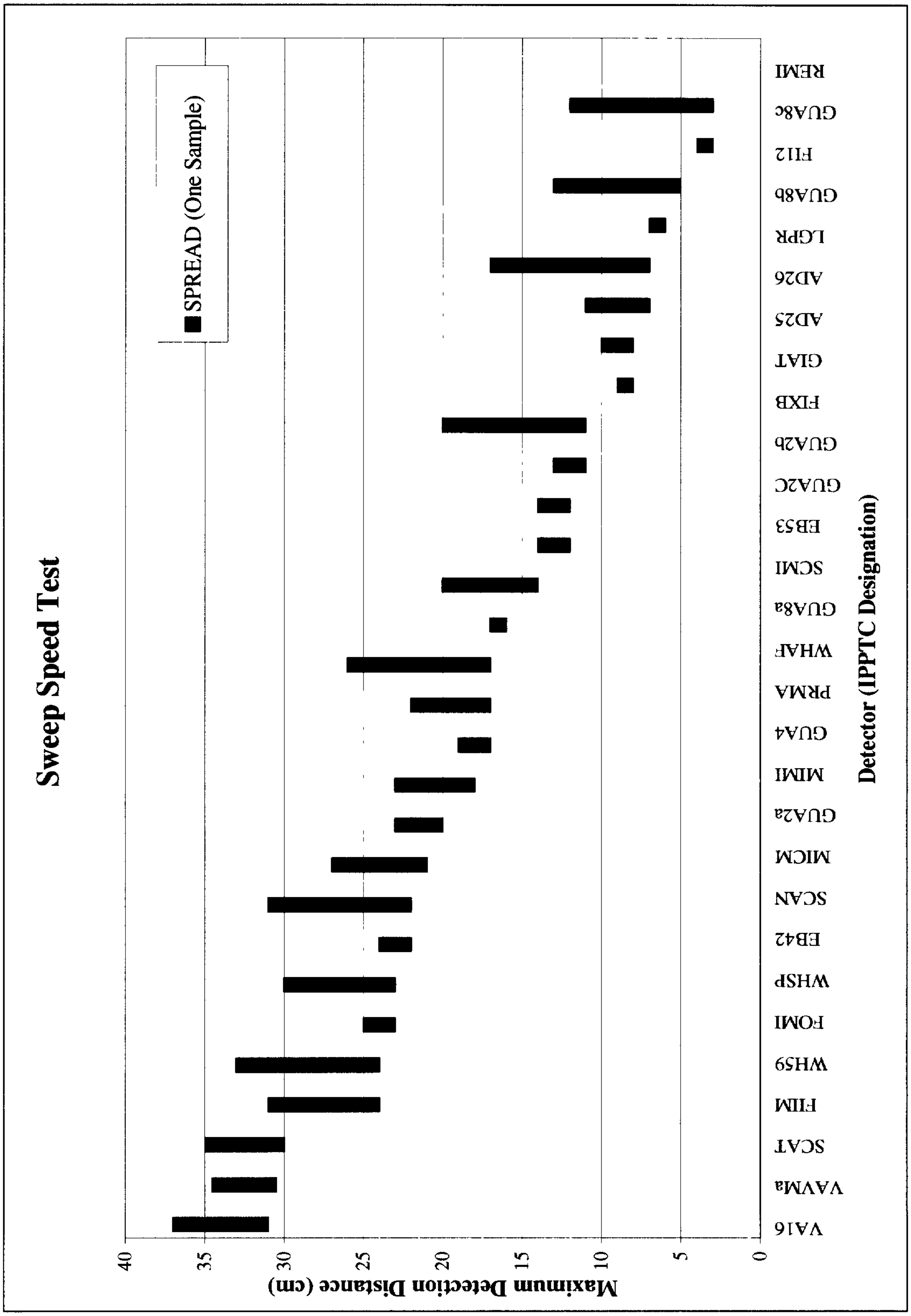

Figure 10: *Range of variation of maximum detection distance as a function of detector head sweep speed for all detectors.*

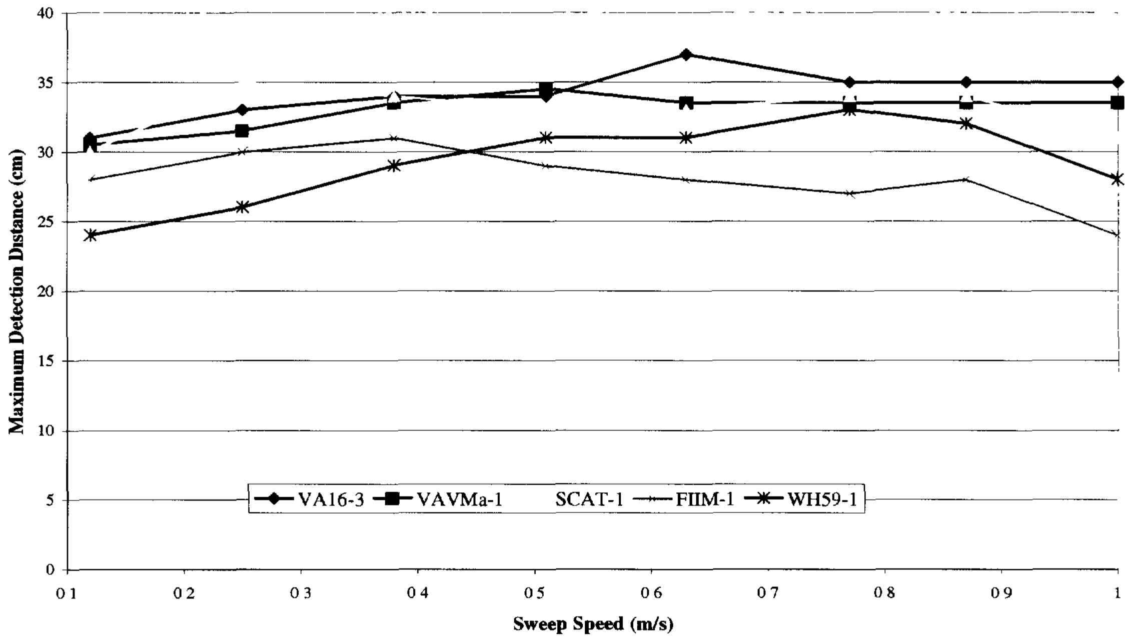

Figure 11: *Maximum detection distance vs sweep speed for selected detectors (chart 1 of 6)*

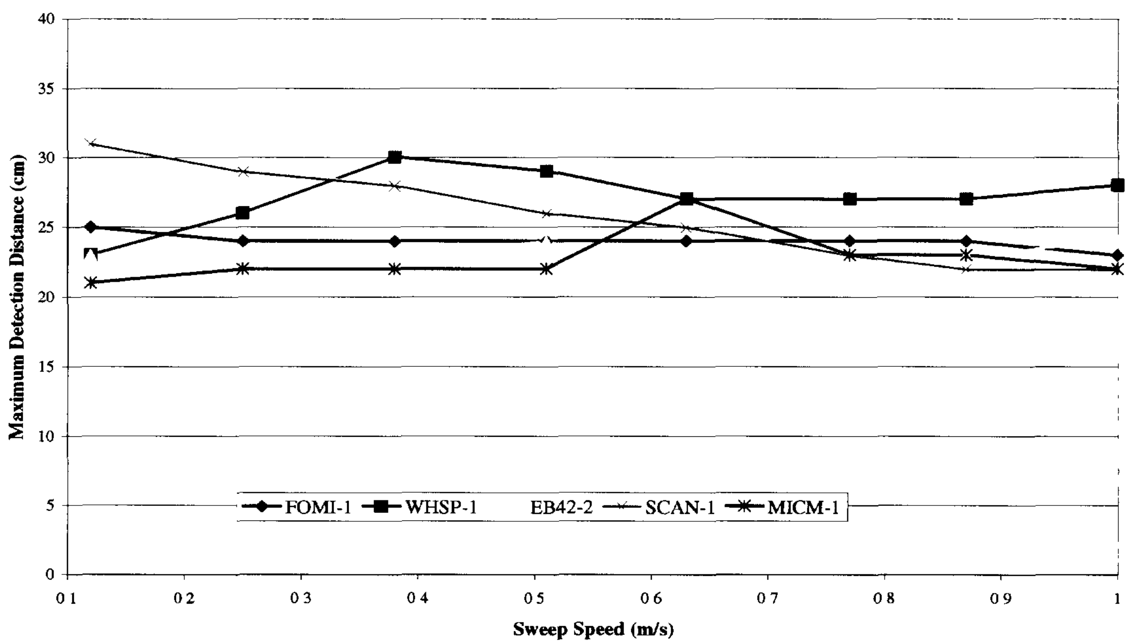

Figure 12: *Maximum detection distance vs sweep speed for selected detectors (chart 2 of 6)*

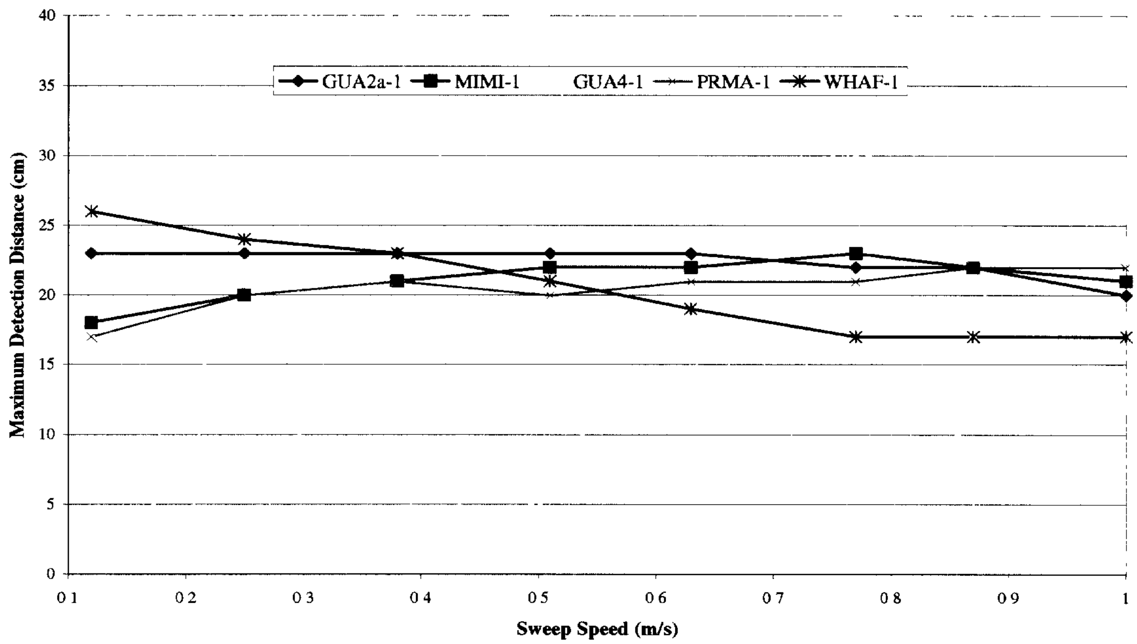

Figure 13: *Maximum detection distance vs sweep speed for selected detectors (chart 3 of 6)*

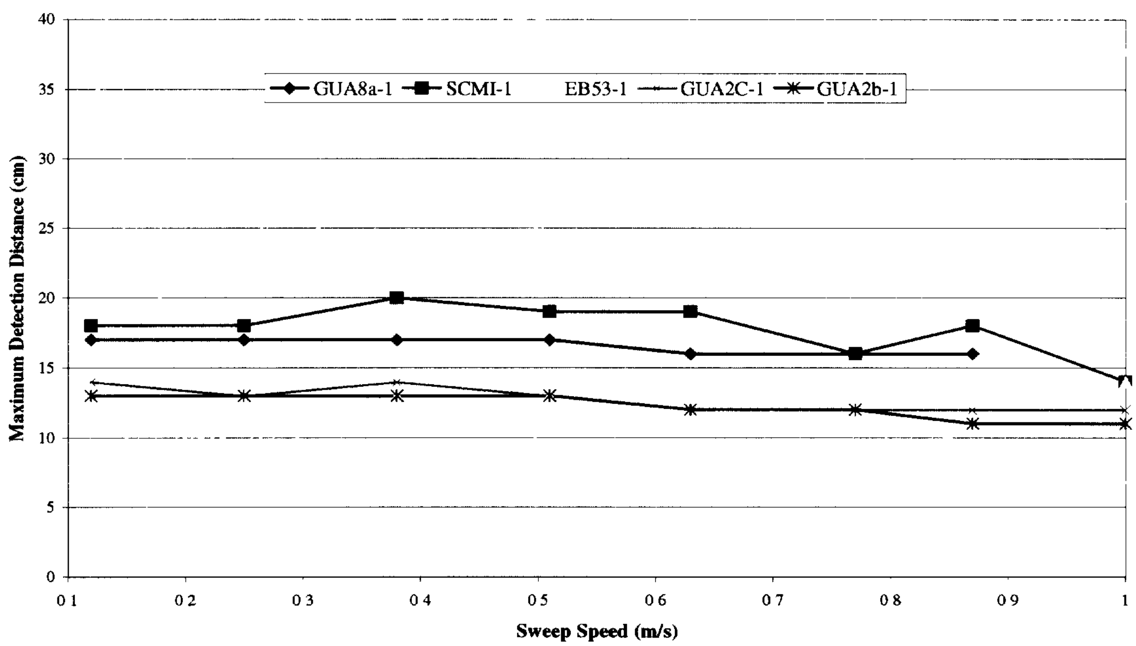

Figure 14: *Maximum detection distance vs sweep speed for selected detectors (chart 4 of 6)*

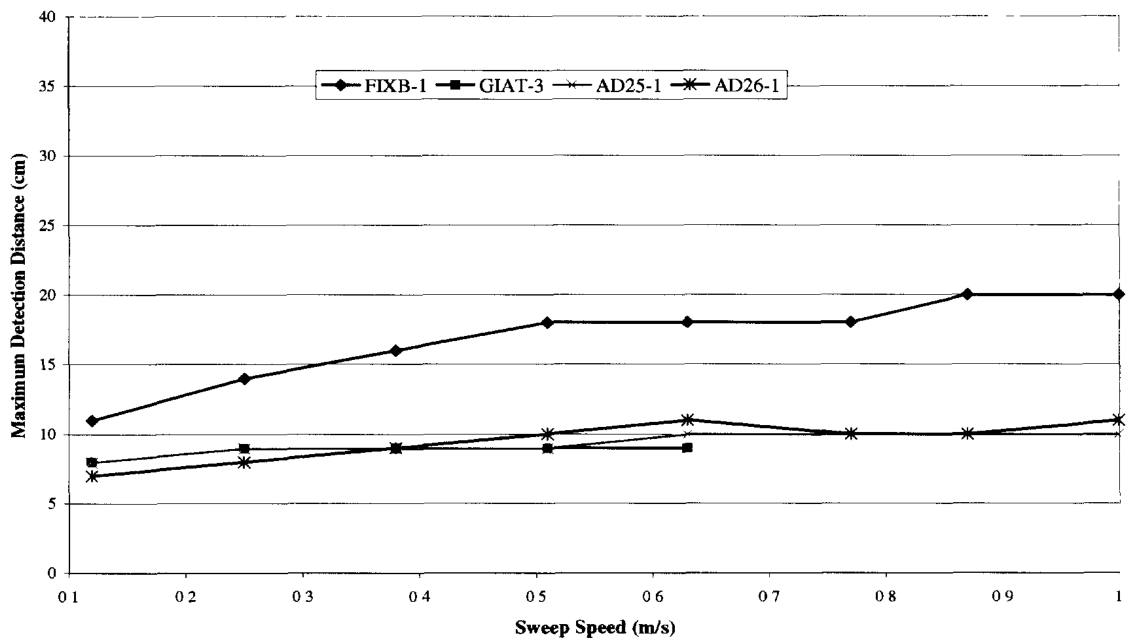

Figure 15: *Maximum detection distance vs sweep speed for selected detectors (chart 5 of 6)*

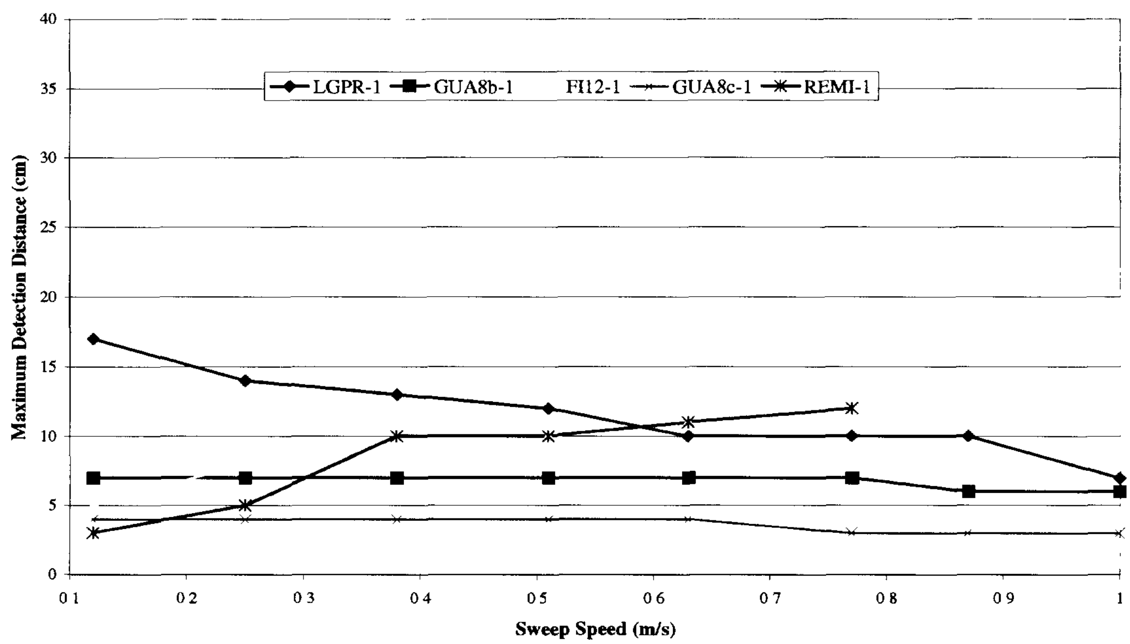

Figure 16: *Maximum detection distance vs sweep speed for selected detectors (chart 6 of 6)*

5. Moisture Test

Previous experience had showed [7] that if any moisture gathers on the search head, even as little as what can be expected when working over dew-covered vegetation, certain detectors suffer significant loss of sensitivity. The magnitude of the loss depends on the amount of moisture on the head. A reduction in sensitivity, without a warning to the operator, when the search head comes in contact with water could be potentially dangerous. The purpose of this test was to determine the extent that moisture on the sensor head affected the sensitivity of a detector. Only one sample of each detector was tested.

The test consisted of measuring, after initial warm-up and calibration of the detector, the maximum detection distance of the $\mathbf{M_0}$ target, in vertical orientation, as increasing amounts of water were sprayed on the search head. Because of the varying sizes and shapes of heads used in the detectors it took somewhat different number of "squirts" of water to go from "dry" to "completely wet" (where water started to drip from search head) for the various detectors. The amount of water was controlled such that this range of wetness was achieved incrementally and represented subjectively by a finite number of steps (e.g.,six).

Figure 17 shows the total variation in maximum detection distance for all the detectors over the entire range of wetness. The details of this variation as a function of moisture level from "dry" to "completely wet" for each detector are shown in Figures 18-23, which should be viewed mainly as graphical reporting of raw data. Any trend seen in Figures 18-23 must be confirmed by a number of repetitions of the test. As well, they should not be used to compare relative loss of sensitivity of two different detectors for a level of wetness that falls between the two extremes.

Due to the time taken to complete a Moisture Test (typically 20-30 minutes), the results from this test included some effect of drift that is difficult to separate. However, if a detector is found to have a much larger variation in the Moisture Test than in the Drift Test, the effect of moisture can be inferred. There was a wide range of variation in sensitivity among the various detectors with increasing amount of water on the sensor head. In some detectors the sensitivity remained essentially constant. In others it resulted in differences of 10 cm in the maximum detection distance. One detector, the Schiebel ATMID (SCAT-1), stopped operating properly after some amount of water had accumulated on the sensor head. The detector produced continuous detection tones despite repeated attempts at initial setup adjustments. It functioned properly the following day.

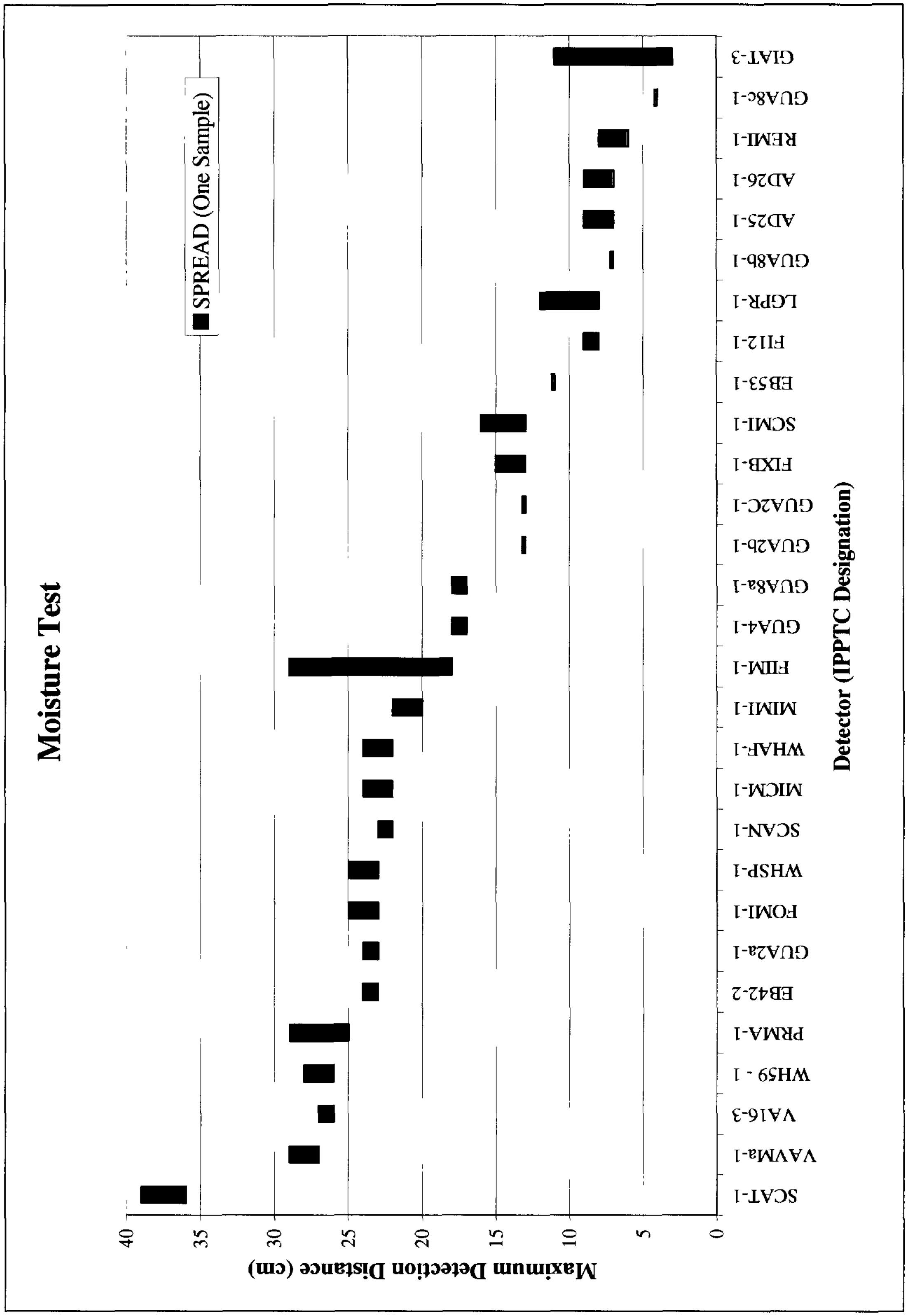

Figure 17: *Range of variation of maximum detection distance as a function of wetness of detector head for all detectors.*

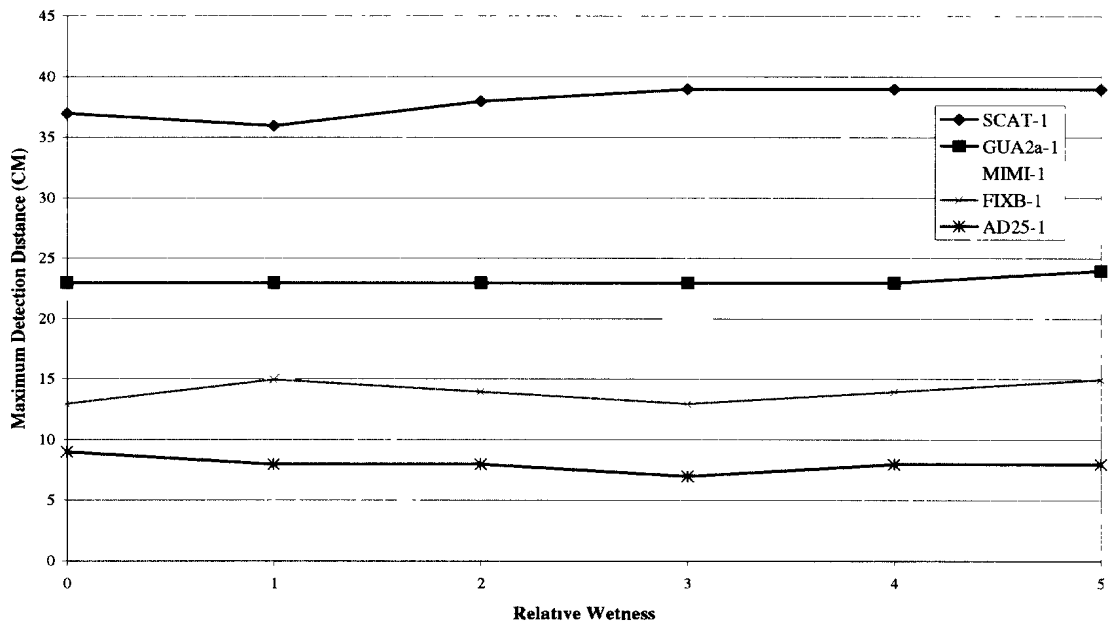

Figure 18: *Maximum detection distance vs wetness of detector head for selected detectors (chart 1 of 6).*

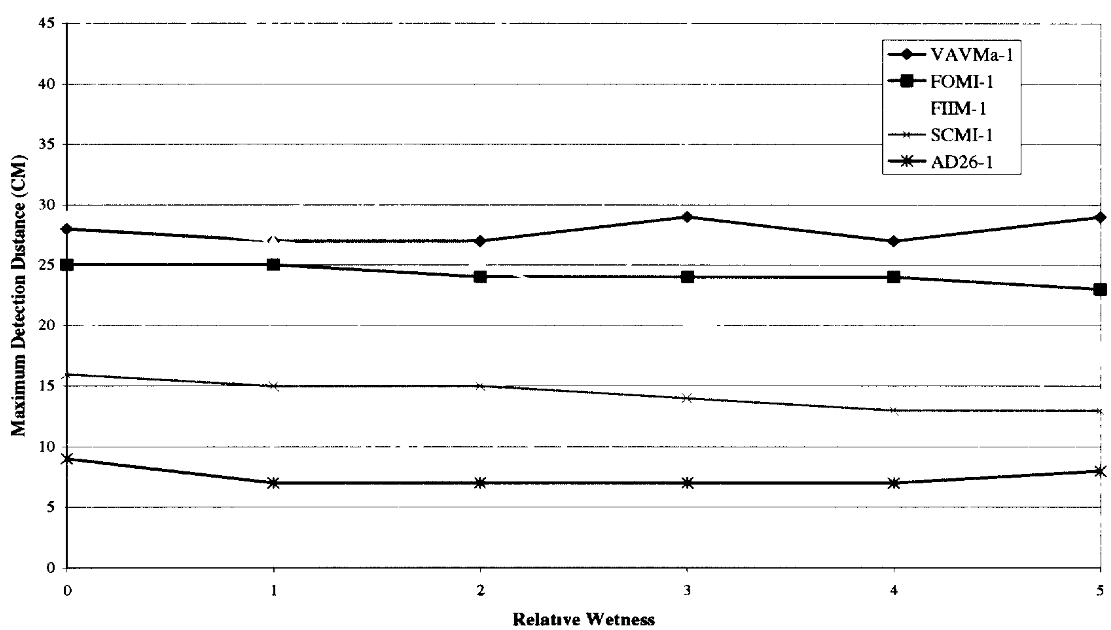

Figure 19: *Maximum detection distance vs wetness of detector head for selected detectors (chart 2 of 6).*

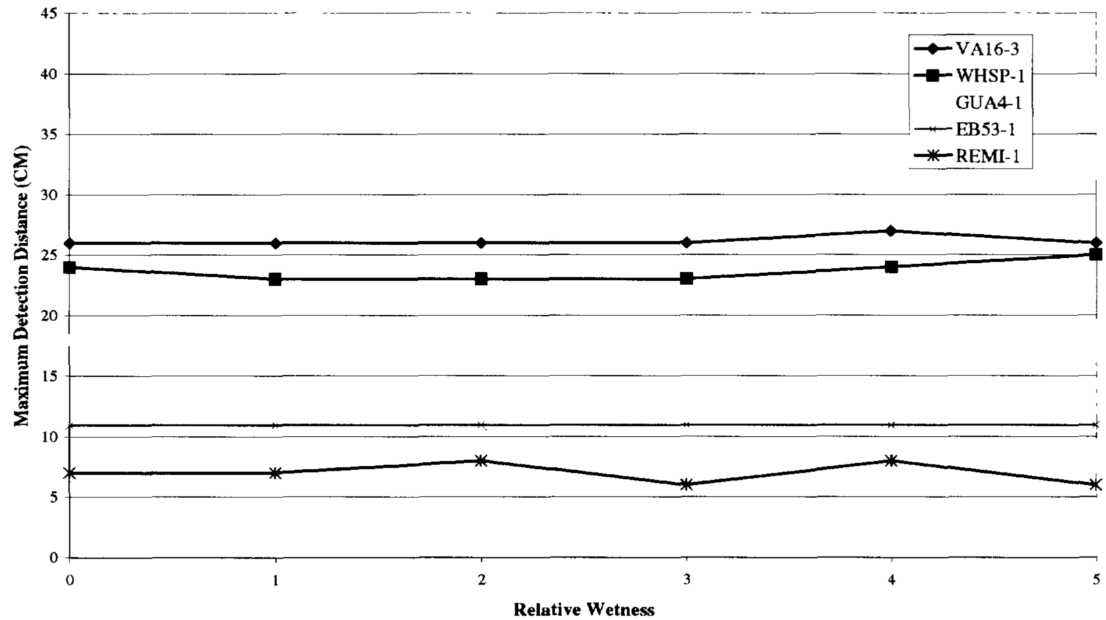

Figure 20: *Maximum detection distance vs wetness of detector head for selected detectors (chart 3 of 6).*

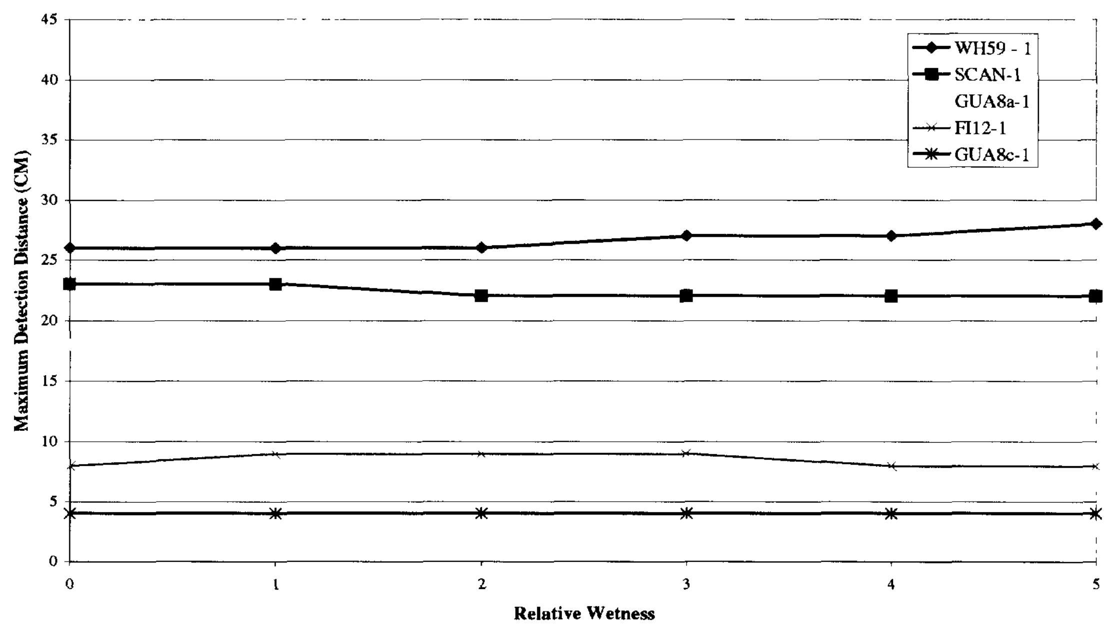

Figure 21: *Maximum detection distance vs wetness of detector head for selected detectors (chart 4 of 6).*

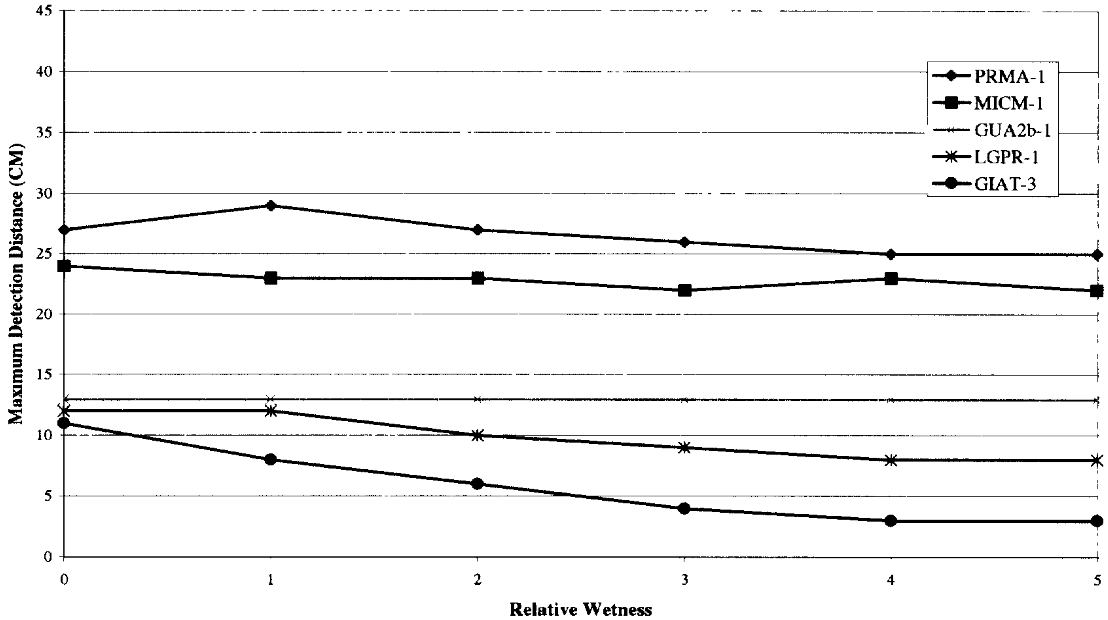

Figure 22: *Maximum detection distance vs wetness of detector head for selected detectors (chart 5 of 6).*

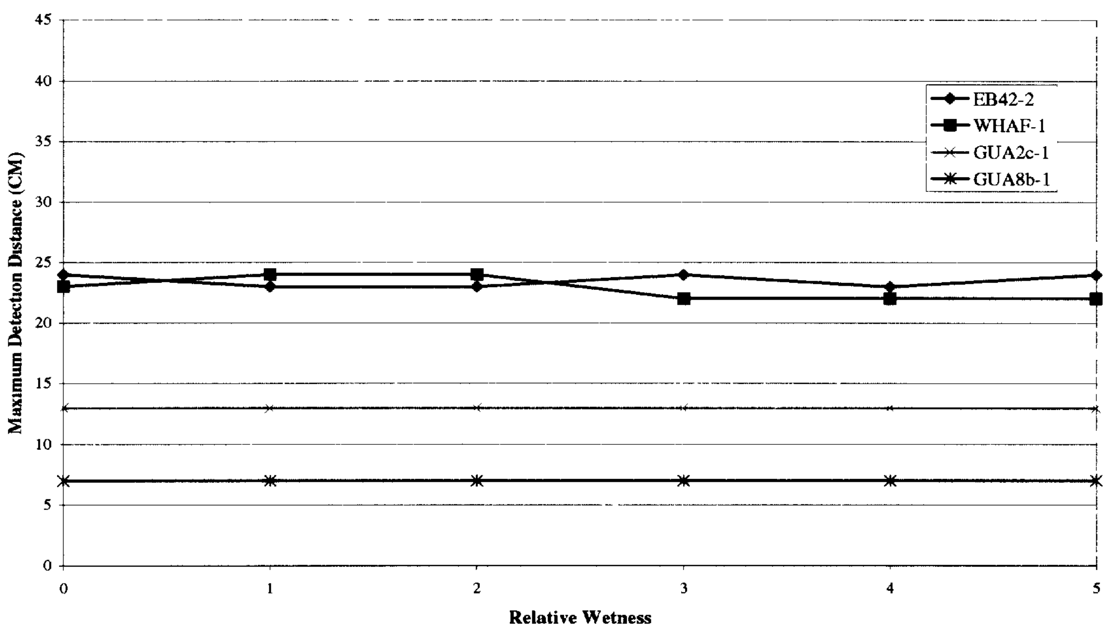

Figure 23: *Maximum detection distance vs wetness of detector head for selected detectors (chart 6 of 6).*

6. Sensitivity Test

Manufacturers' specifications often indicate the maximum distance at which their detector can detect a specified quantity of metal without mentioning any other characteristics of the piece of metal. Also, most manufacturers provide a "test piece" to check the proper functioning of their detector. Sometimes a "test piece" of one vendor is not detected well by another vender's detector. It is well kown that the distance at which a metal object can be detected by a metal detector depends on the object's size, shape, material, orientation, among other parameters. Thus the selection of a suitable set of objects or targets is very important for the purpose of comparing performances of various detectors and results of tests conducted at different times and by different agencies. The targets used are described in detail in Section 1.6. The purpose of this test was to measure the maximum distance at which a detector can detect each of these targets.

Raw data showing the maximum distances at which each target was detected by the various detectors are presented in Table 5. The same data is shown graphically in Figures 24 to 34. Three targets (**PMN-2, M_0** and **STP**) were measured with two samples of the detectors while all others were measured with only one sample of the detectors. An arrow on top of a chart bar in the figures and a number in bold in the tables both indicate a detection distance greater than that shown (see 1.5). Care must be excercised in interpreting these cases. Of particular interest are Figures 27-34 which show the detection distances for the low-metal content targets (**PMA-2, PMA-3, Type 72A, R2M2, M_0, I_0,G_0** and **STP**). These graphs illustrate the relative ability of the detectors to detect a given low-metal content target. The sensitivity data is presented differently in Figures 35 to 63 where the maximum distances at which a given detector detects the various targets are shown. These graphs illustrate the relative ability of a given detector to detect the various items in the target set.

The potential users of the data presented in this section are warned against interpreting the detection distances of the various targets as distances at which they may be detected under operational conditions. The results obtained with targets in air in a controlled laboratory environment should be used only as guidelines to assess relative performance of the detectors and to compare results of similar tests done by others. The results can also be used to identify detectors which do not have the minimum required detection distance for targets of interest in a given demining operation since a target is not likely to be detected at a greater distance in soil than in air. In addition to factors, such as calibration, drift, sweep speed and ambient noise that can affect the detection distance, the operators themselves could have a significant influence. A number of operators were used in the course of this test although the same operator was used to measure the detection distances of all the targets by a given detector. Computer processing of the recorded signal would have reduced the operator bias.

Table 5: *Maximum detection in cm for all targets. Only one working sample each of EB42 and GUA8b was available for testing (Section 1.7) A number in bold indicates a distance greater than that shown (Section 1.5). "No Det" indicates that the target was not detected even on contact with sensor head.*

Model	PMN	PMN-2		PMD-6	PMA-2	PMA-3	Type 72A	R2M2	M_0		I_0	G_0	STP	
	First Sample	First Sample	Second Sample	First Sample	First Sample	First Sample	First Sample	First Sample	First Sample	Second Sample	First Sample	First Sample	First Sample	Second Sample
AD25	23	13	9	11	4	7	6	5	9	11	7	5	3	3
AD26	23	10	15	9	3	6	6	4	8	10	6	4	3	5
EB42	61	34	NO DATA	30	16	16	16	9	24	NO DATA	16	12	12	NO DATA
EB53	25	13	13	12	5	7	7	2	11	8	7	4	2	1
FI12	26	14	16	11	4	5	4	0	8	9	5	2	2	3
FIIM	**26**	**26**	44	**25**	15	16	19	12	25	29	18	14	12	16
FIXB	39	22	24	20	10	12	9	7	14	15	10	7	7	8
FOMI	58	35	25	29	17	19	18	13	24	17	18	15	15	8
GIAT	30	17	22	15	5	7	8	9	9	11	5	[illegible]	5	10
GUA2a	61	36	39	30	14	17	13	5	23	25	14	10	9	11
GUA2b	36	19	18	16	6	8	6	3	12	12	7	5	4	3
GUA2c	37	20	20	18	7	8	7	3	14	13	8	6	3	3
GUA4	**32**	28	23	22	10	13	11	8	17	16	12	9	8	5
GUA8a	46	27	29	22	10	14	13	9	18	19	9	10	9	11
GUA8b	22	11	NO DATA	8	2	4	3	[illegible]	7	NO DATA	4	2	[illegible]	NO DATA
GUA8c	15	6	6	5	[illegible]	2	1	[illegible]	4	4	2	[illegible]	[illegible]	[illegible]
LGPR	43	20	21	18	9	12	7	3	13	14	9	5	2	3
MICM	46	26	28	23	12	14	15	11	22	22	15	12	5	5
MIMI	40	29	30	23	13	16	15	13	21	21	14	11	9	9
PRMA	**33**	**33**	36	28	13	15	14	6	23	23	14	6	9	10
REMI	28	13	13	10	[illegible]	2	[illegible]	[illegible]	7	7	2	1	[illegible]	[illegible]
SCAN	46	38	34	32	17	18	19	10	28	24	17	12	11	10
SCAT	**47**	**47**	46	41	25	25	23	8	35	30	23	16	17	19
SCMI	**34**	29	18	21	12	12	12	5	22	14	10	10	8	2
VA16	**39**	**40**	40	**39**	22	24	23	15	34	26	23	19	20	14
VAVMa	38	35	31	30	26	18	17	10	24	22	18	13	13	8
WH59	**44**	33	23	27	16	18	23	7	23	16	17	12	12	6
WHAF	**45**	37	34	28	12	11	11	4	21	22	11	6	6	7
WHSP	**44**	35	36	29	15	20	17	14	23	23	17	18	16	14
MAX	61	47	46	41	26	25	23	15	35	30	23	19	20	19
MIN	15	6	6	5	[illegible]	2	[illegible]	[illegible]	4	4	2	[illegible]	[illegible]	[illegible]

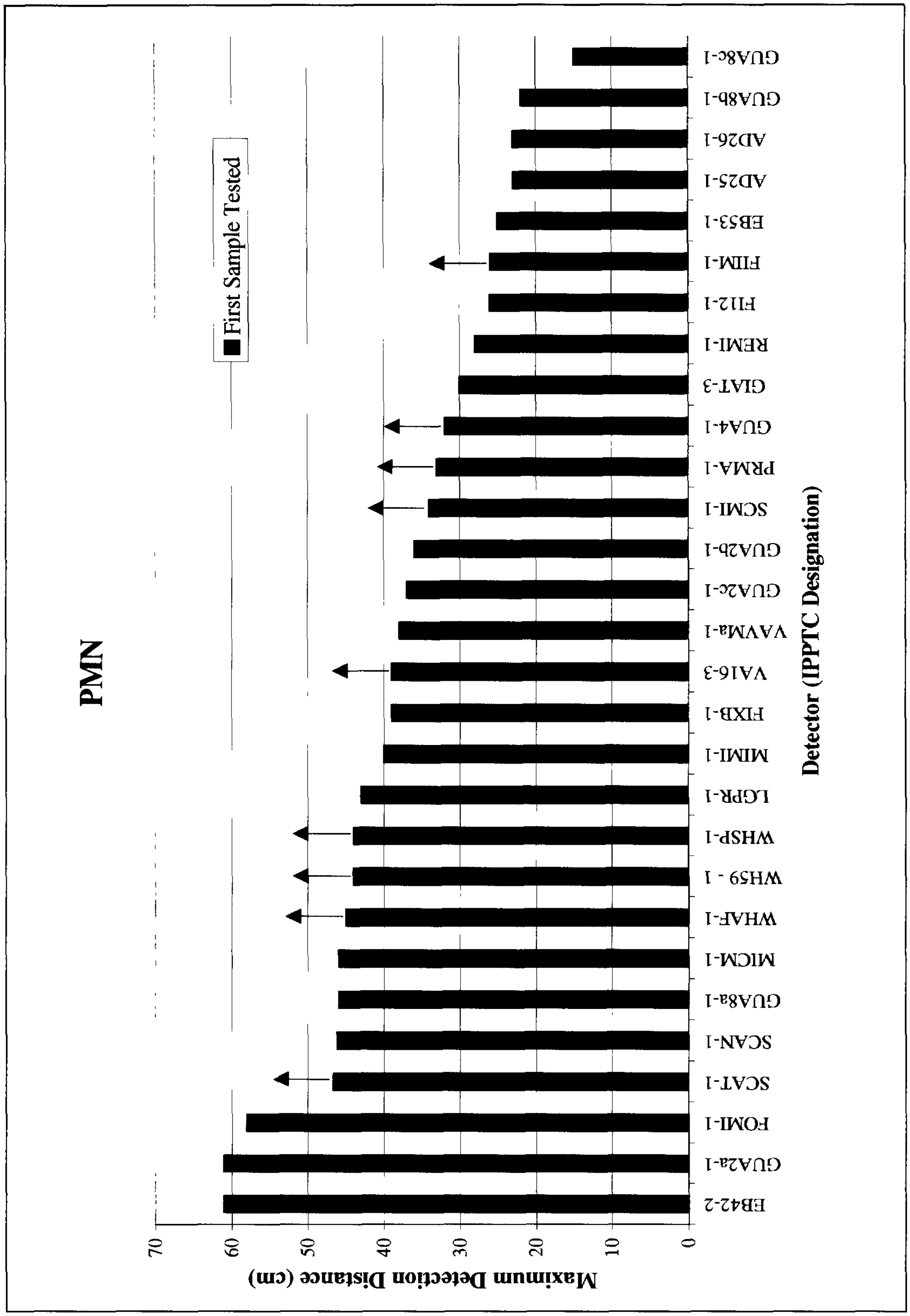

Figure 24: *Maximum detection distance for* **PMN** *(Z-2-11). Arrows indicate greater than (Section 1.5).*

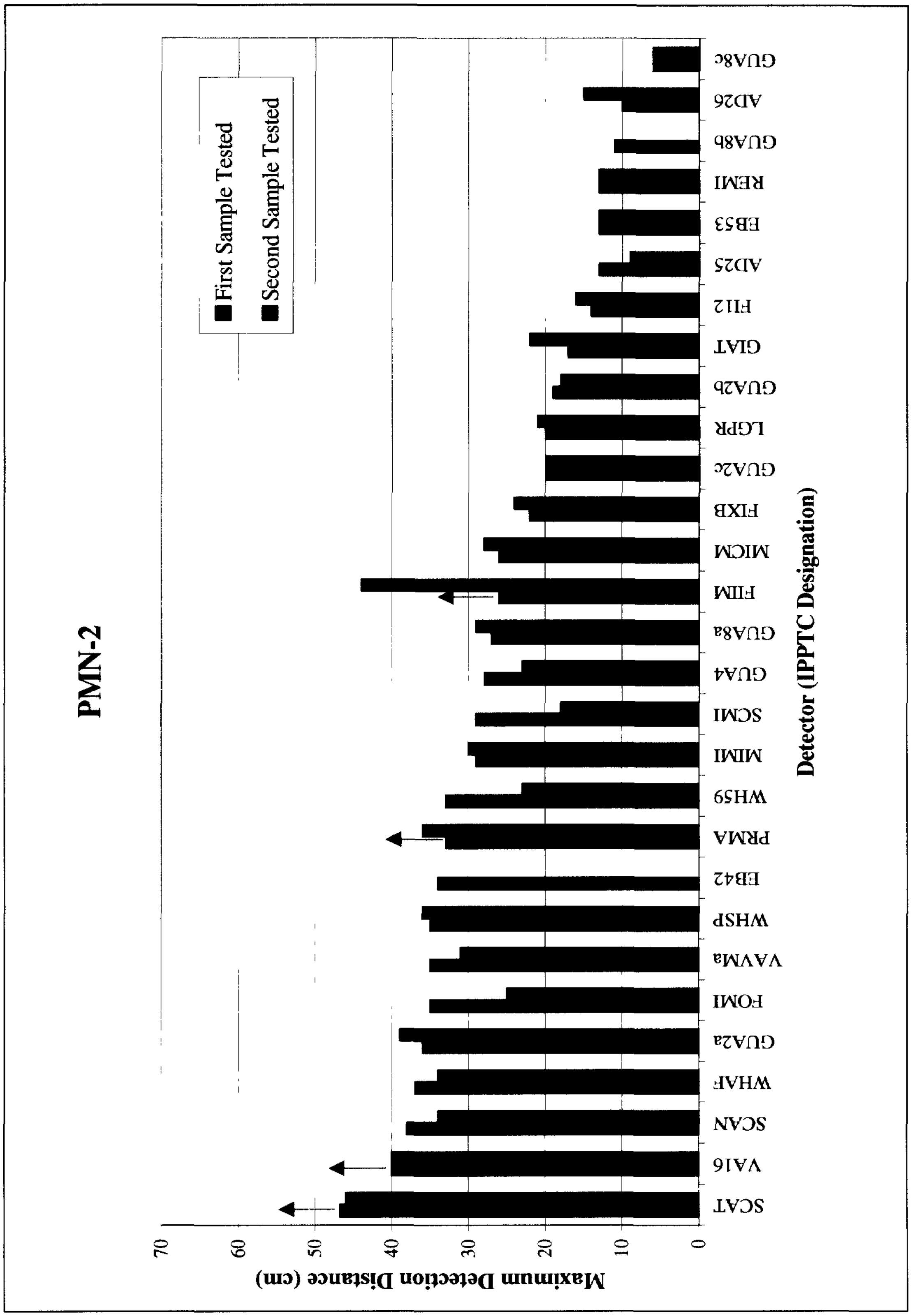

Figure 25: *Maximum detection distance for* **PMN-2** *(Z-3-02). Arrows indicate greater than (Section 1.5).*

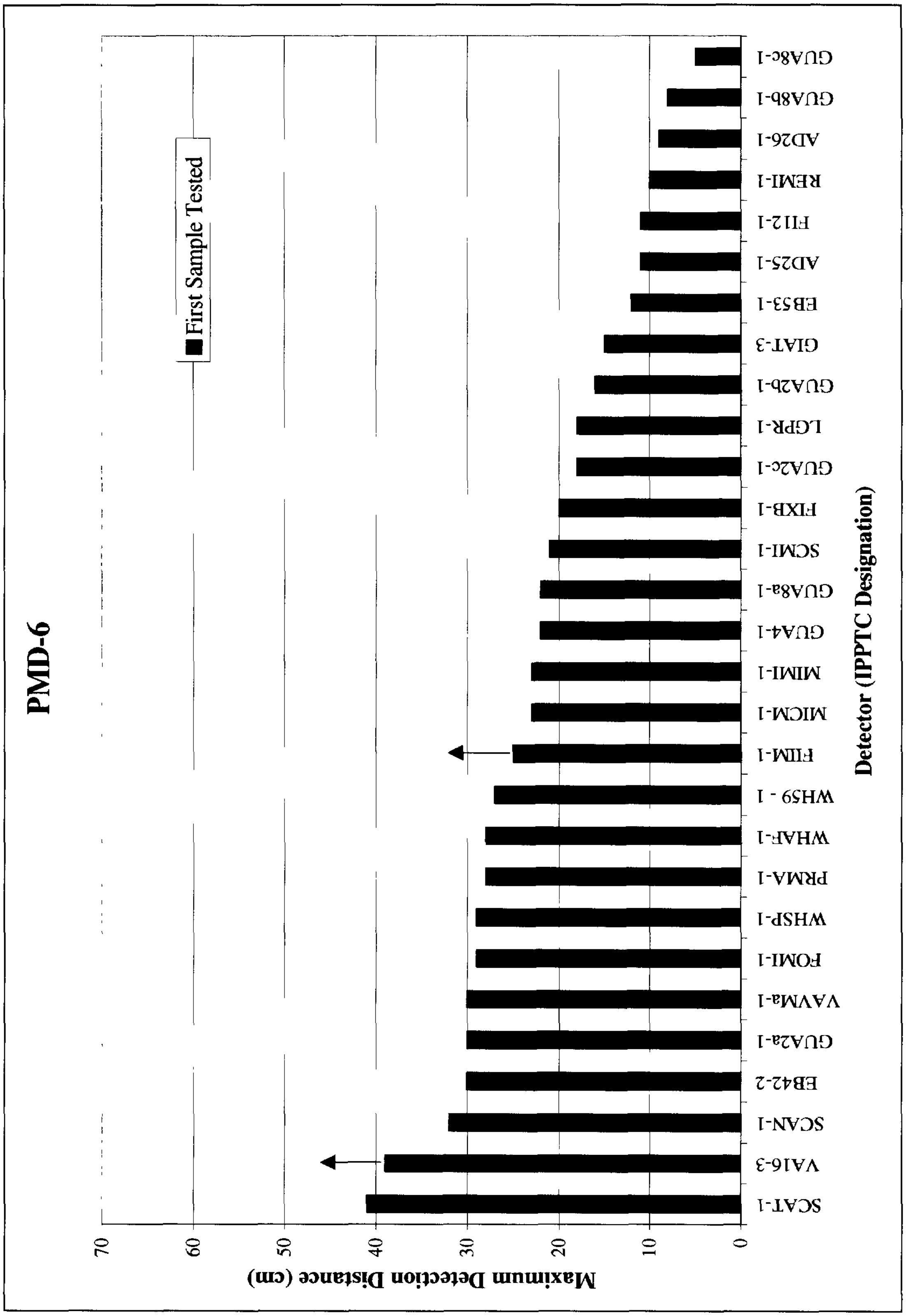

Figure 26: *Maximum detection distance for* **PMD-6** *(Z-0-11). Arrows indicate greater than (Section 1.5).*

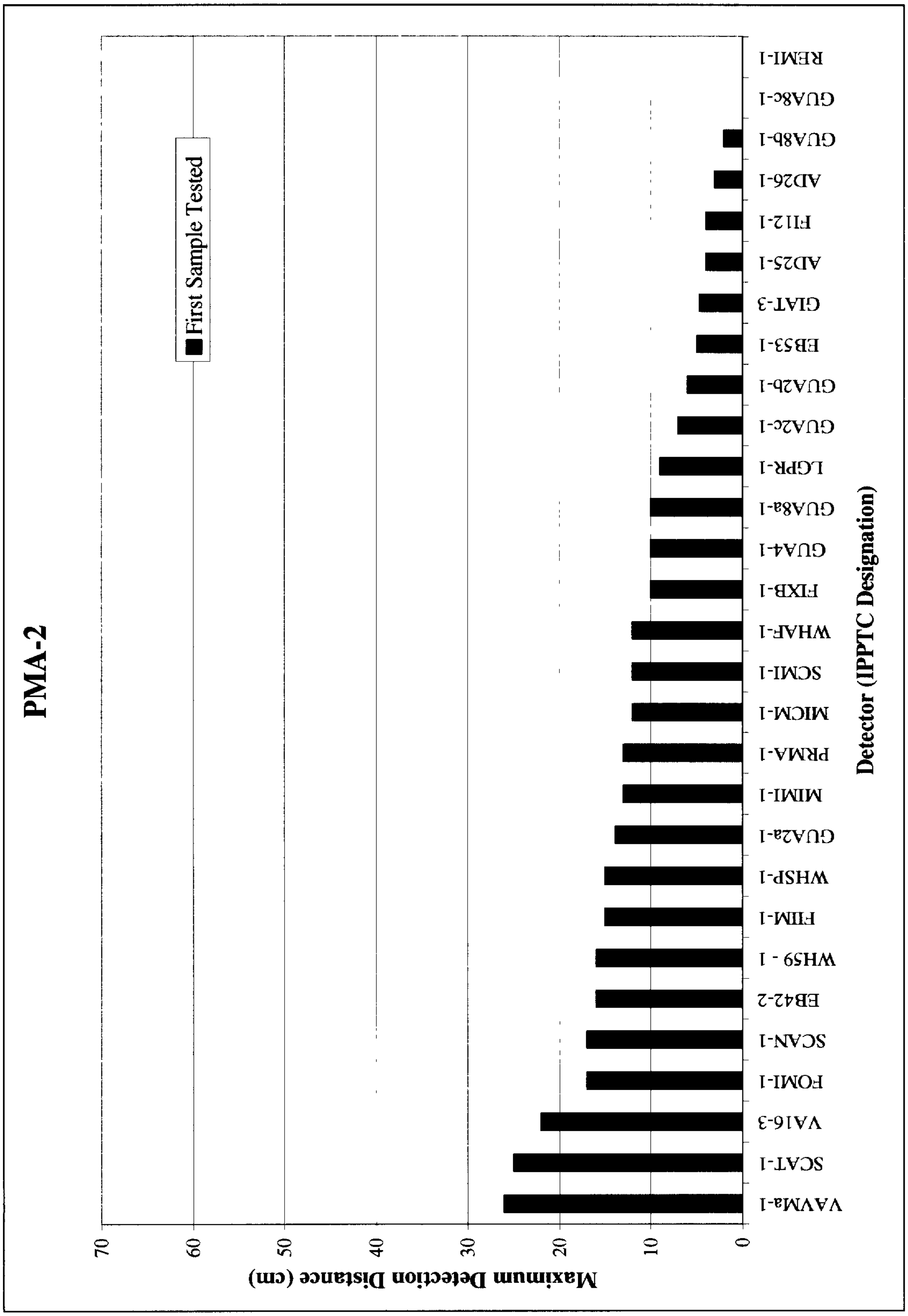

Figure 27: *Maximum detection distance for* **PMA-2** *(Z-4-01).*

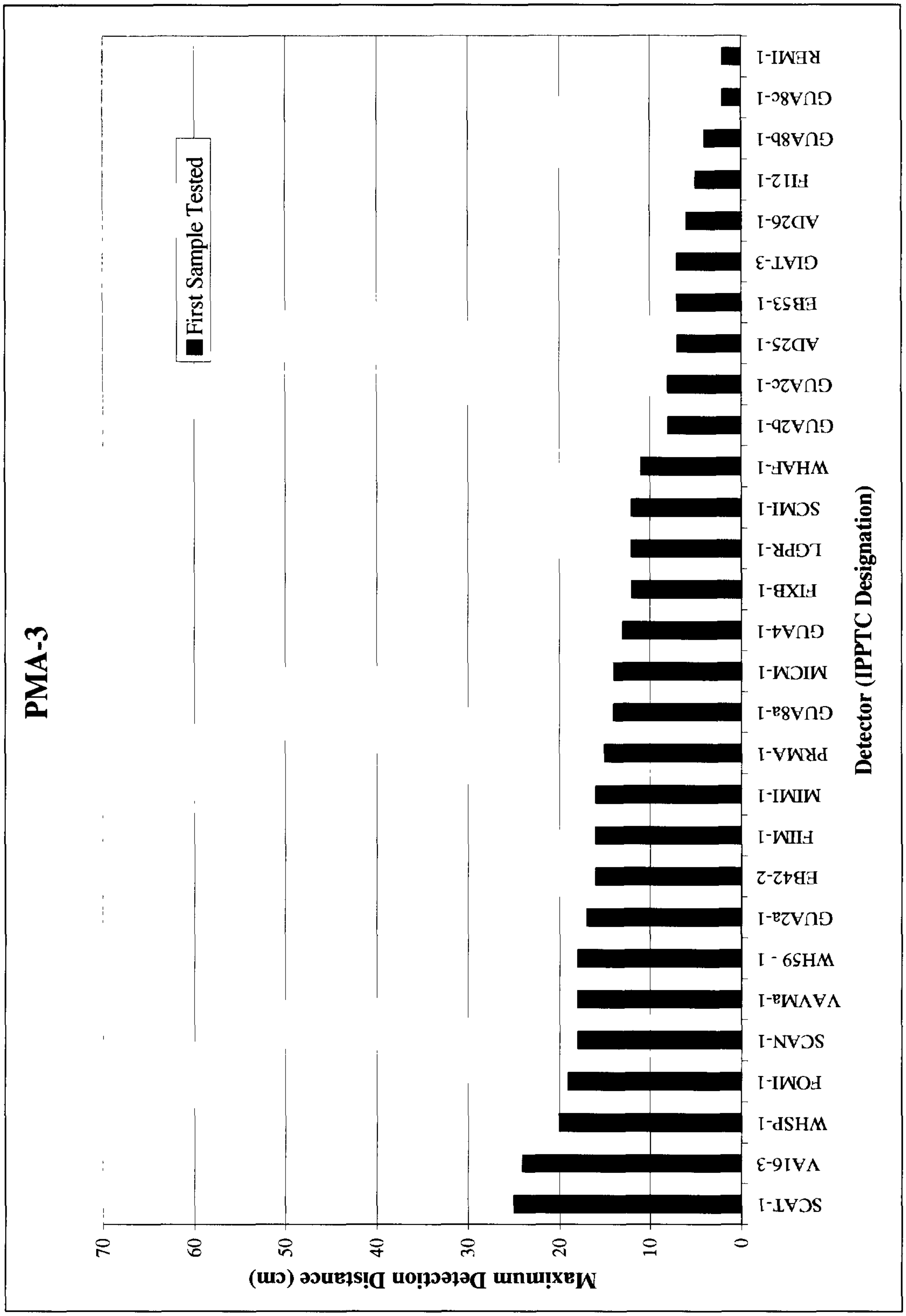

Figure 28: *Maximum detection distance for* **PMA-3** *(Z-1-01).*

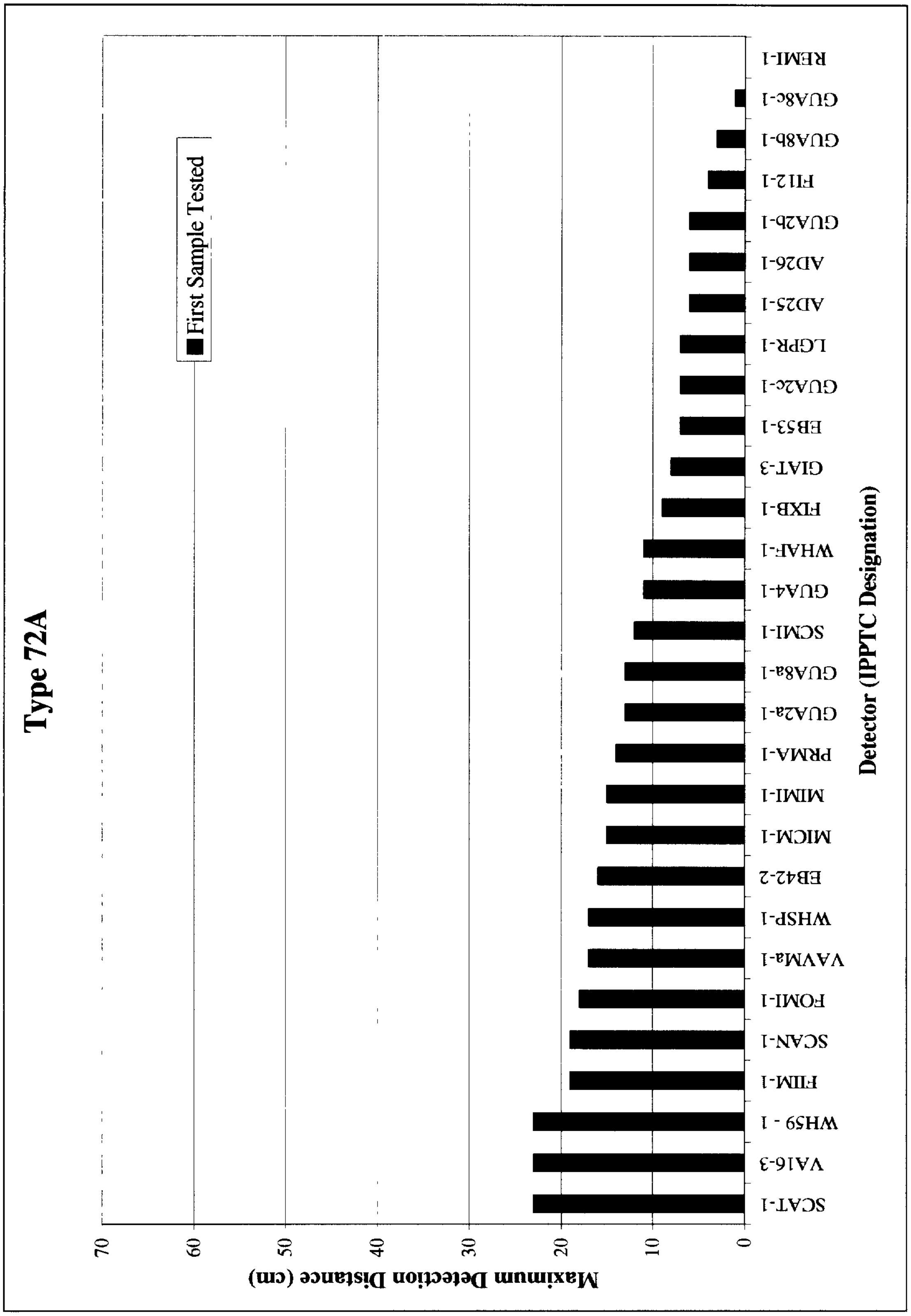

Figure 29: *Maximum detection distance for* **Type 72A** *(Z-5-01)*

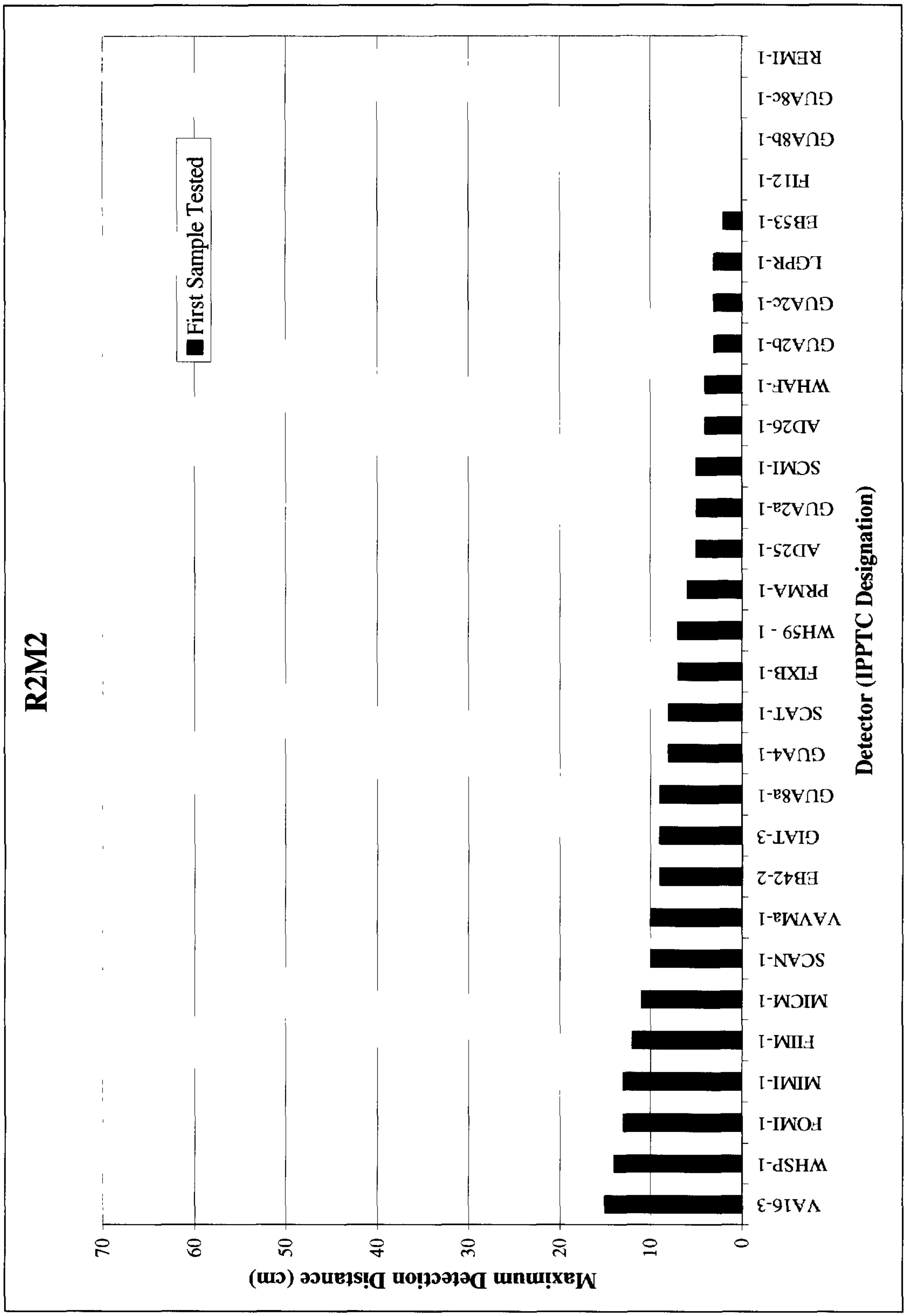

Figure 30: *Maximum detection distance for* **R2M2** *(Z-6-01).*

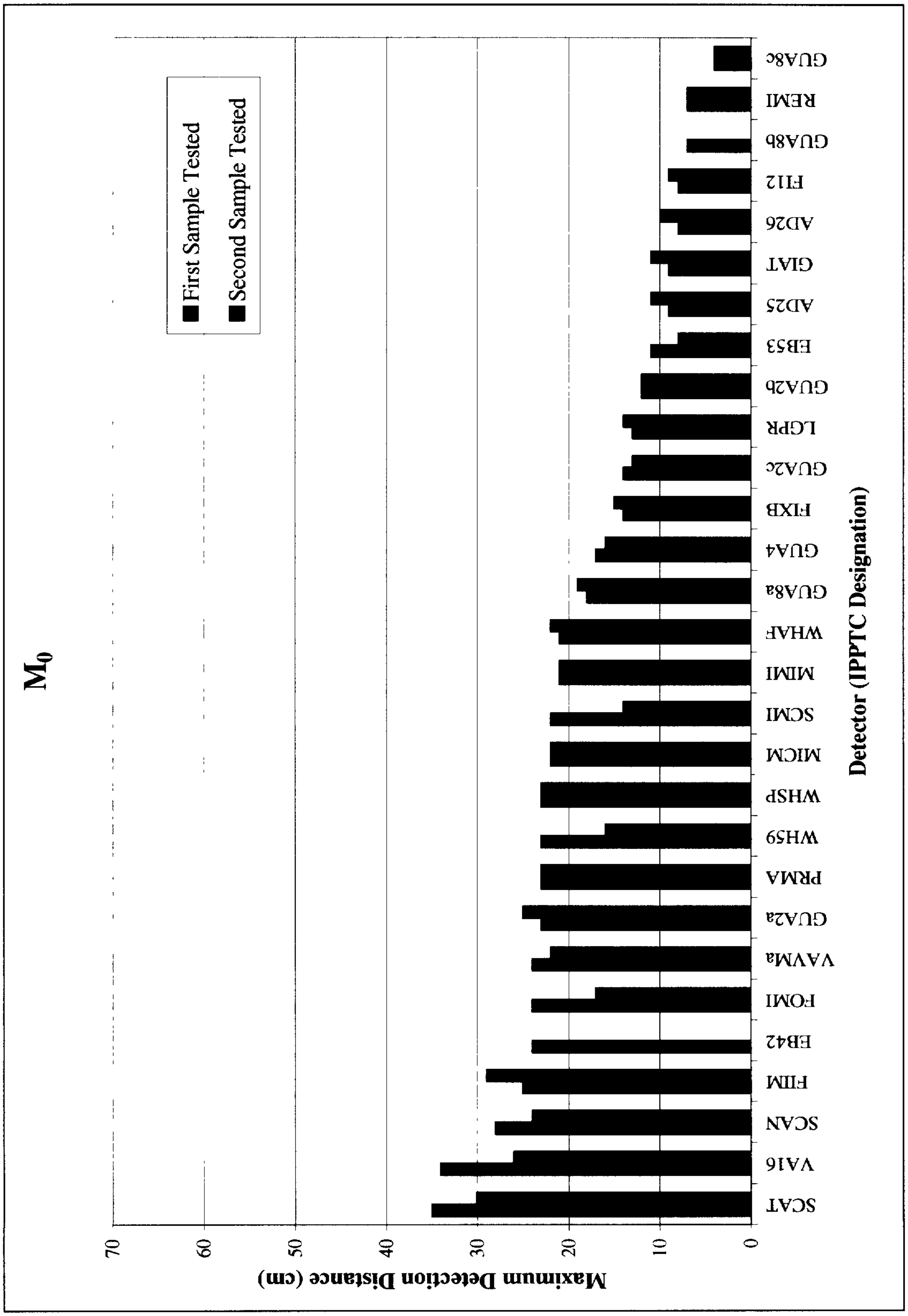

Figure 31: *Maximum detection distance for* M_0 *(Z-10-01)*

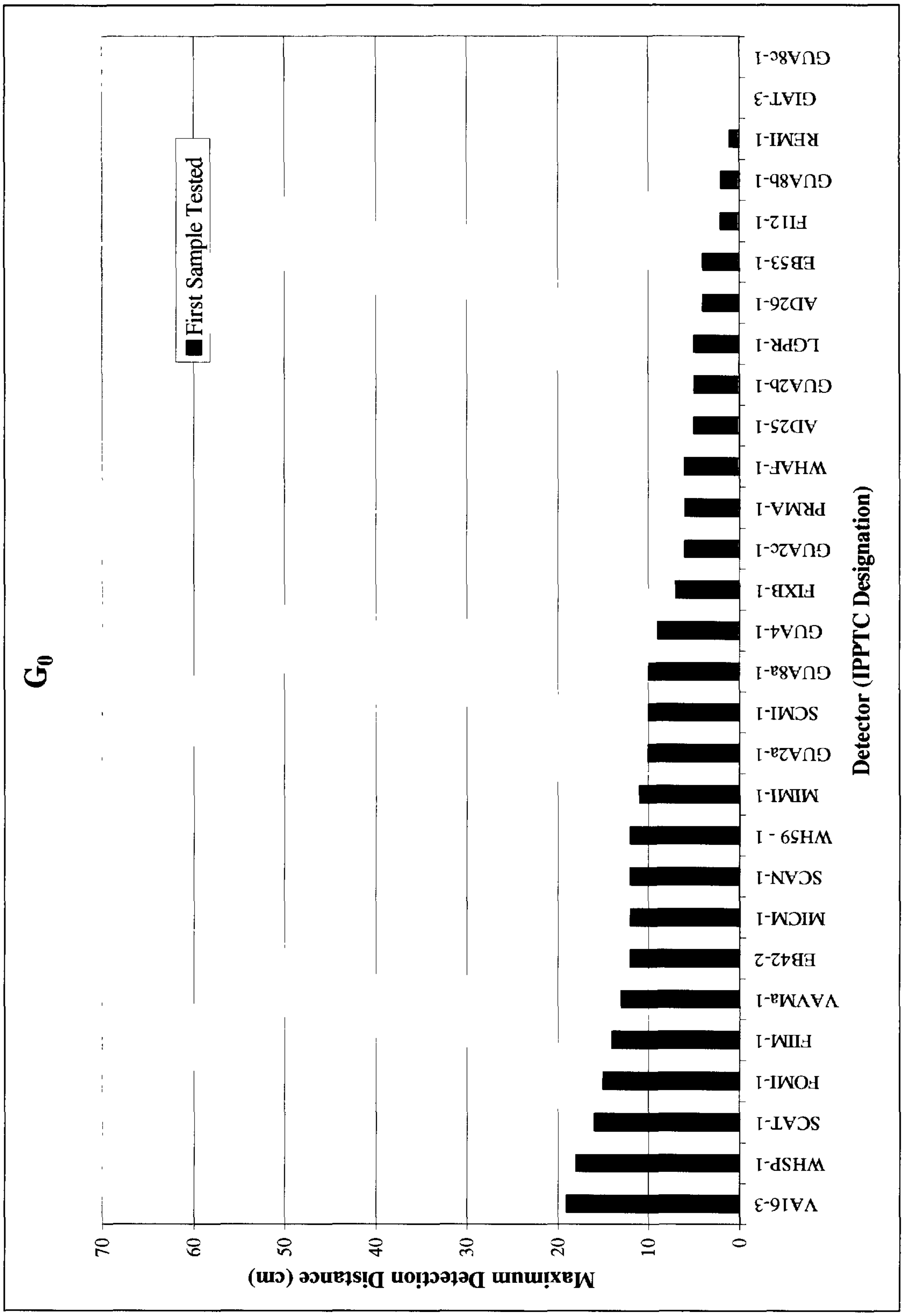

Figure 32: *Maximum detection distance for* G_0 *(Z-7-01).*

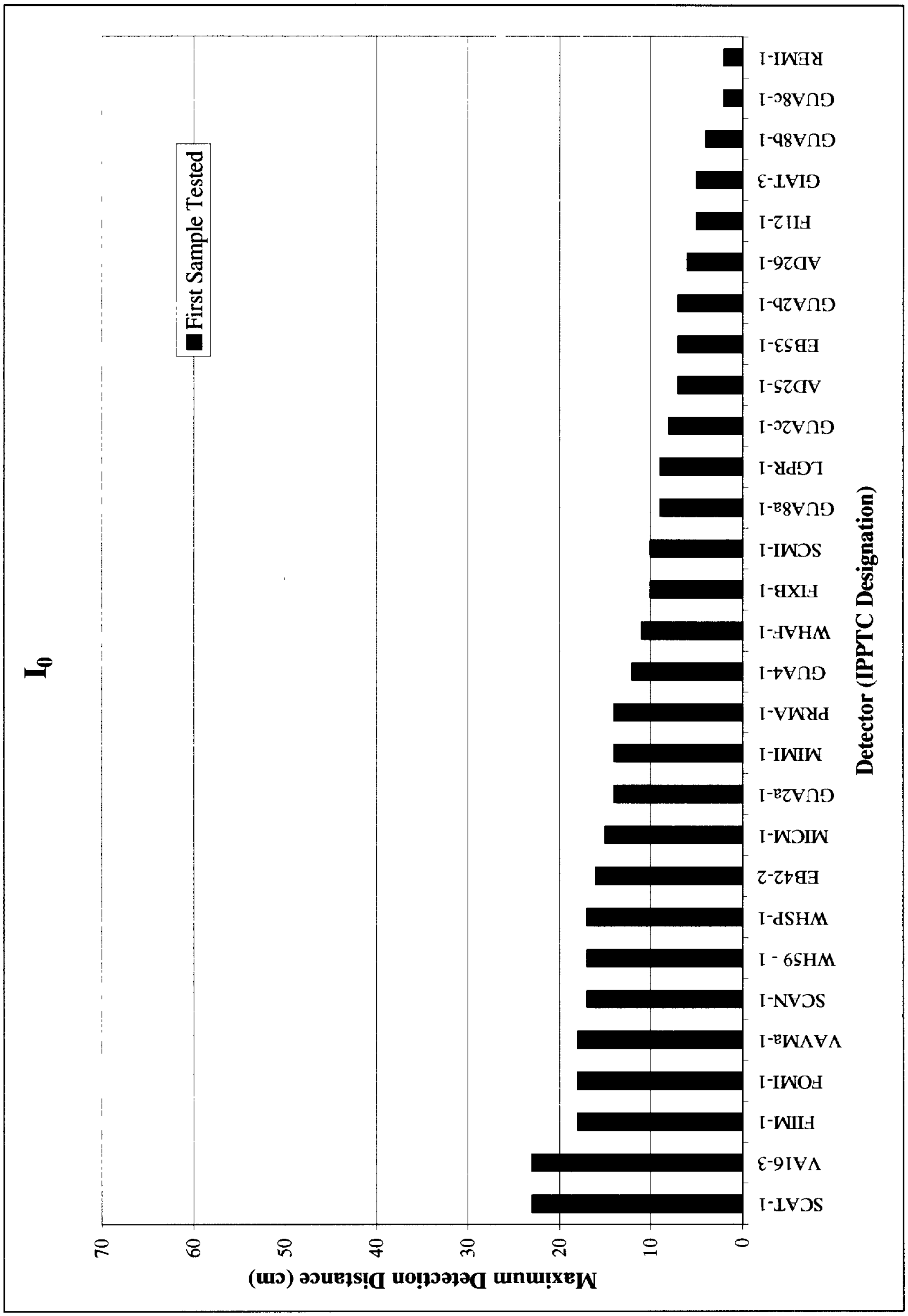

Figure 33: *Maximum detection distance for* $\mathbf{I_0}$ *(Z-8-01).*

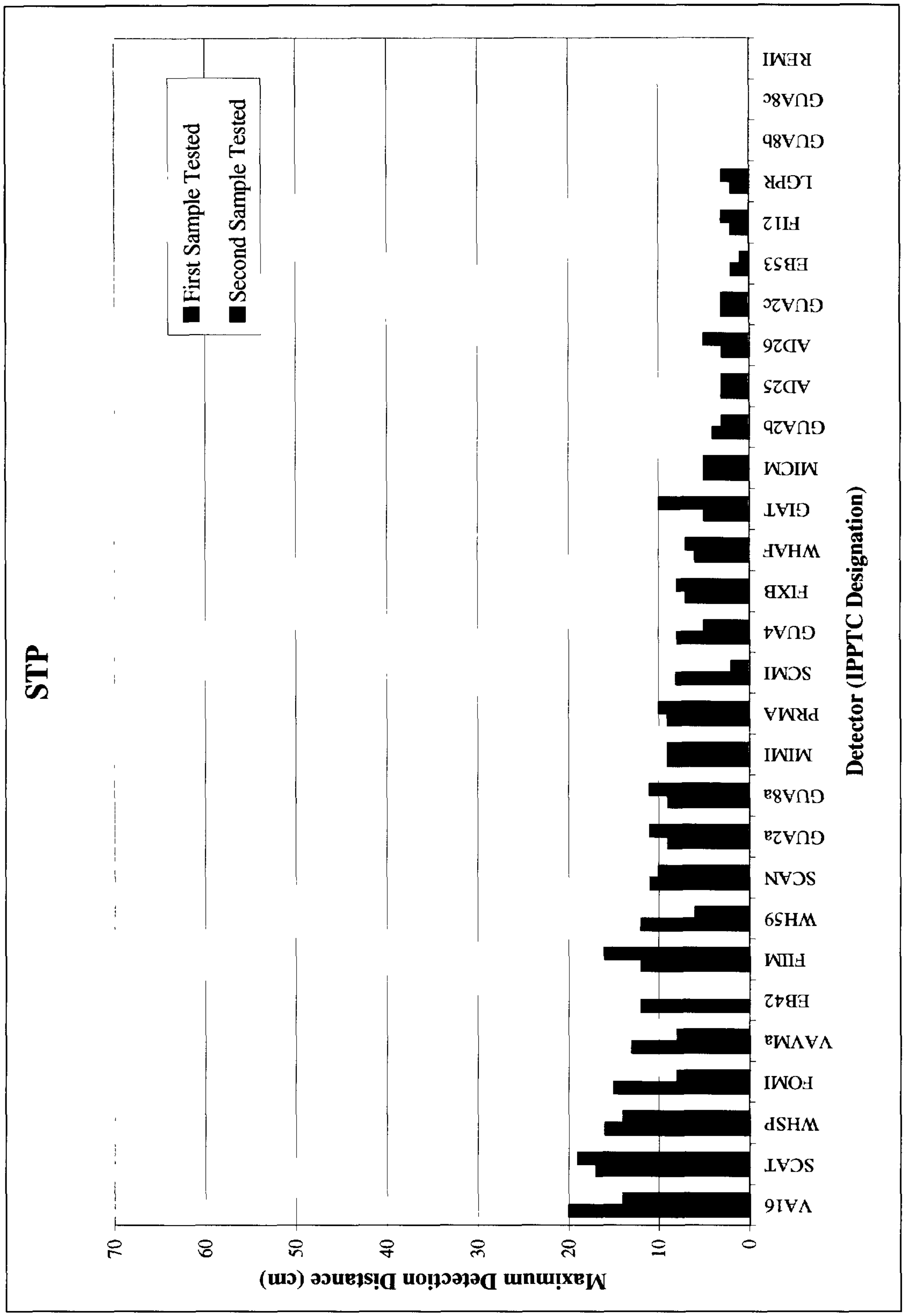

Figure 34: *Maximum detection distance for* **STP** *(STP).*

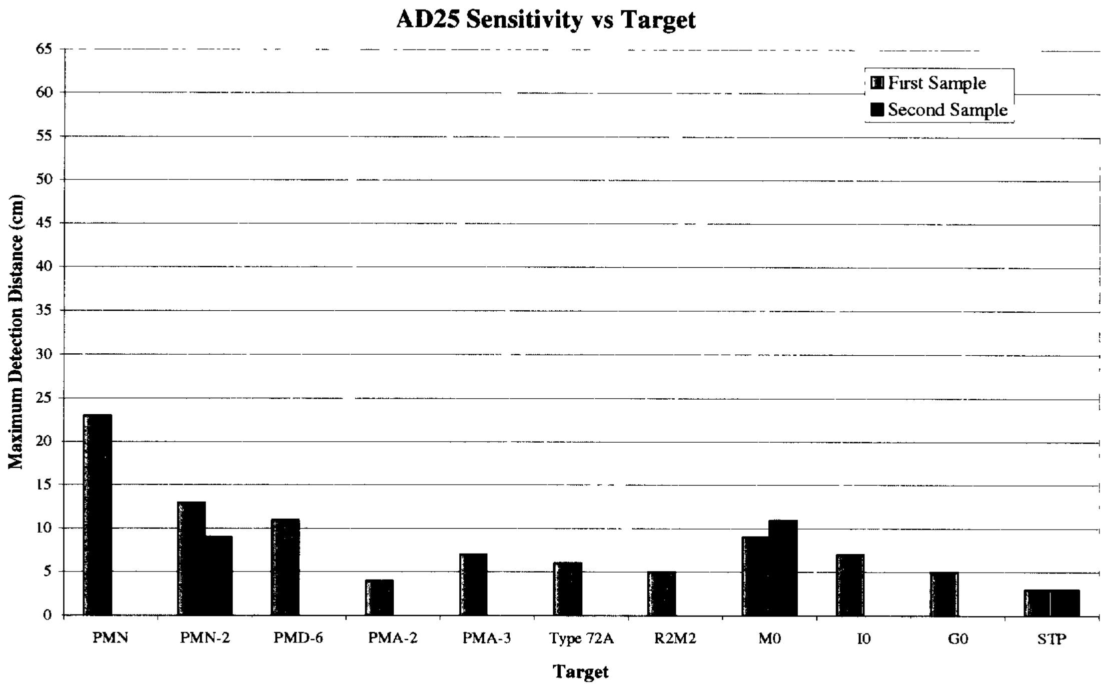

Figure 35: *Maximum detection distance for all targets for the Adams Electronics 2500 detector (***AD25***).*

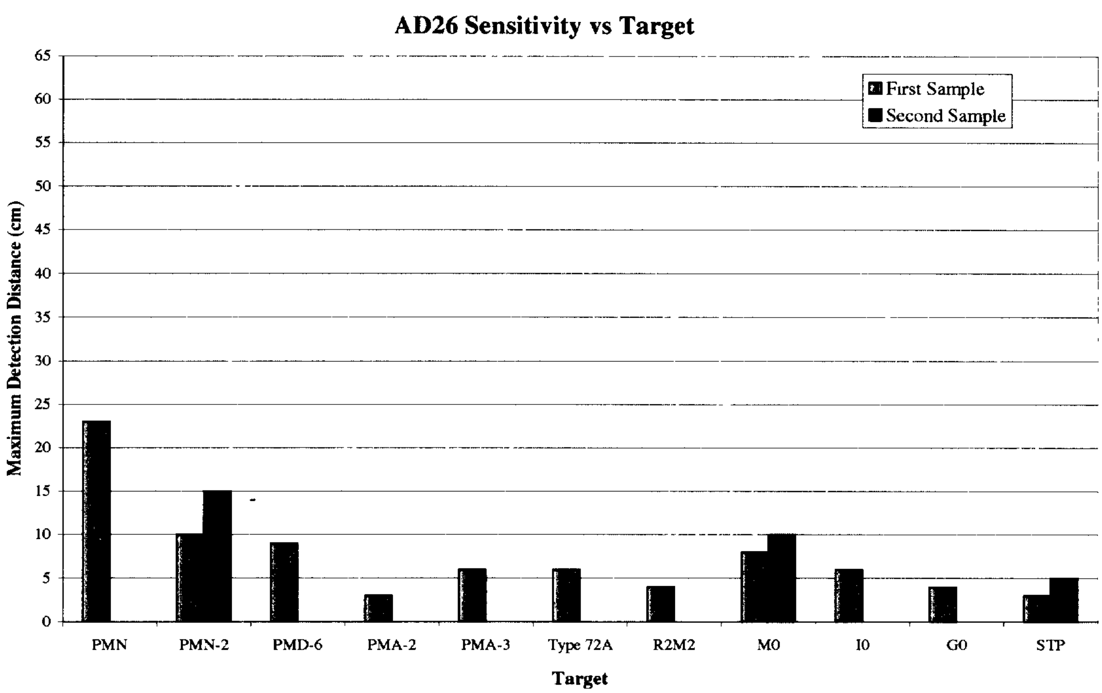

Figure 36: *Maximum detection distance for all targets for the Adams Electronics 2600 detector (***AD26***).*

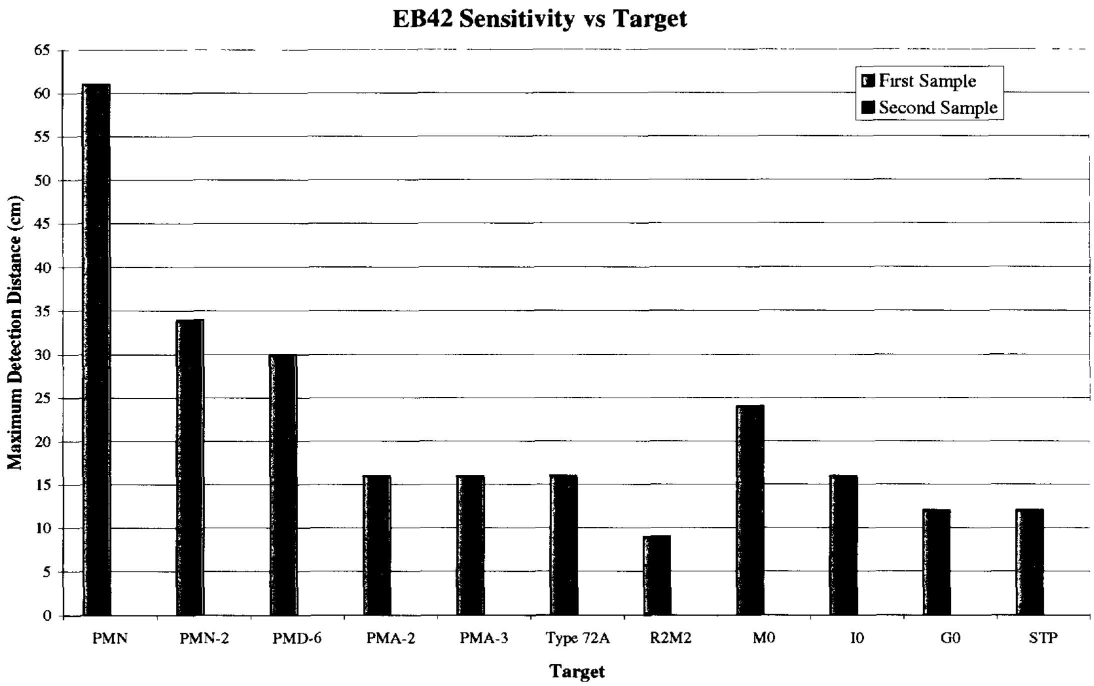

Figure 37: *Maximum detection distance for all targets for the Ebinger EBEX 420GC detector (***EB42***). Only one detector sample available (Section 1.7)*

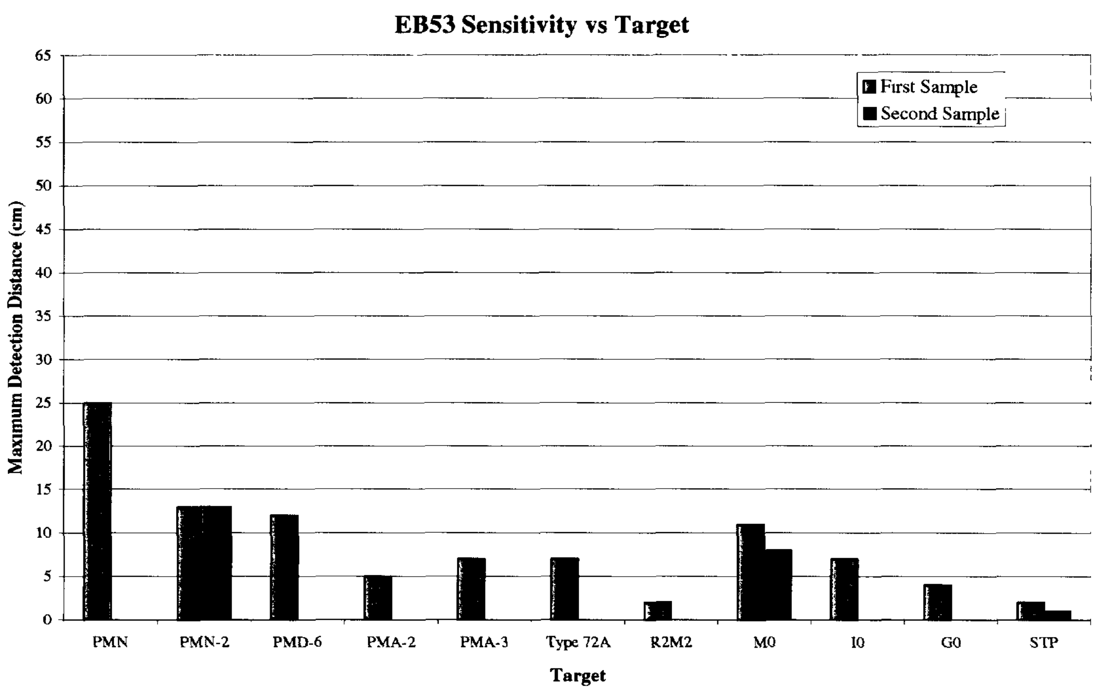

Figure 38: *Maximum detection distance for all targets for the Ebinger EBEX 535 detector (***EB53***).*

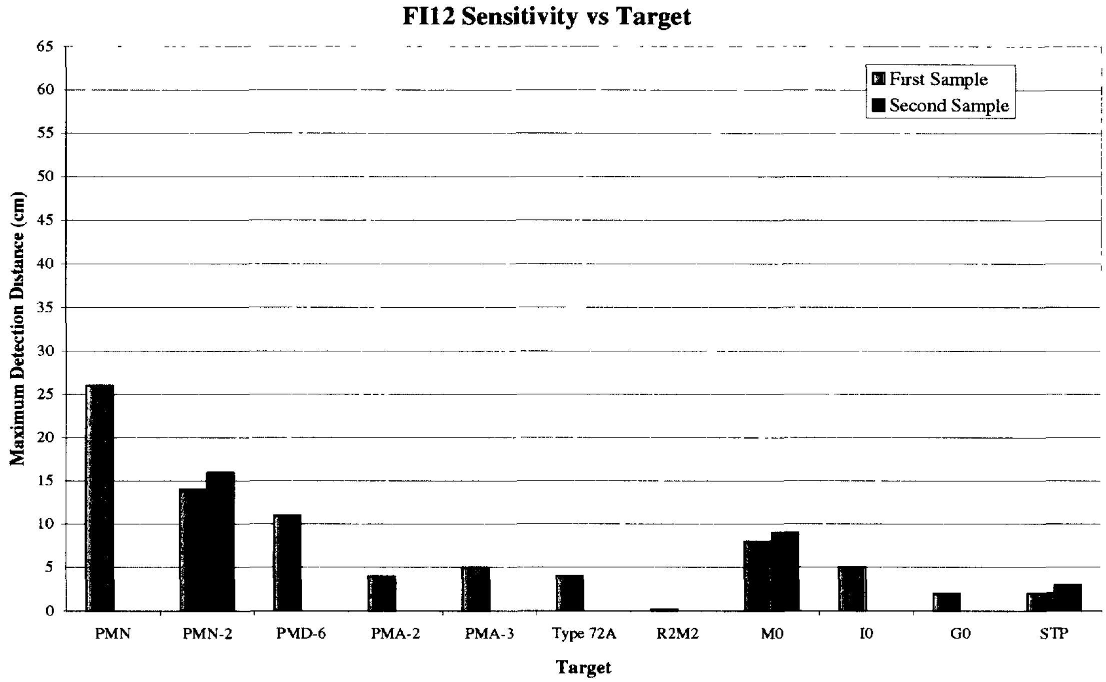

Figure 39: Maximum detection distance for all targets for the Fisher Research 1235X detector (FI12).

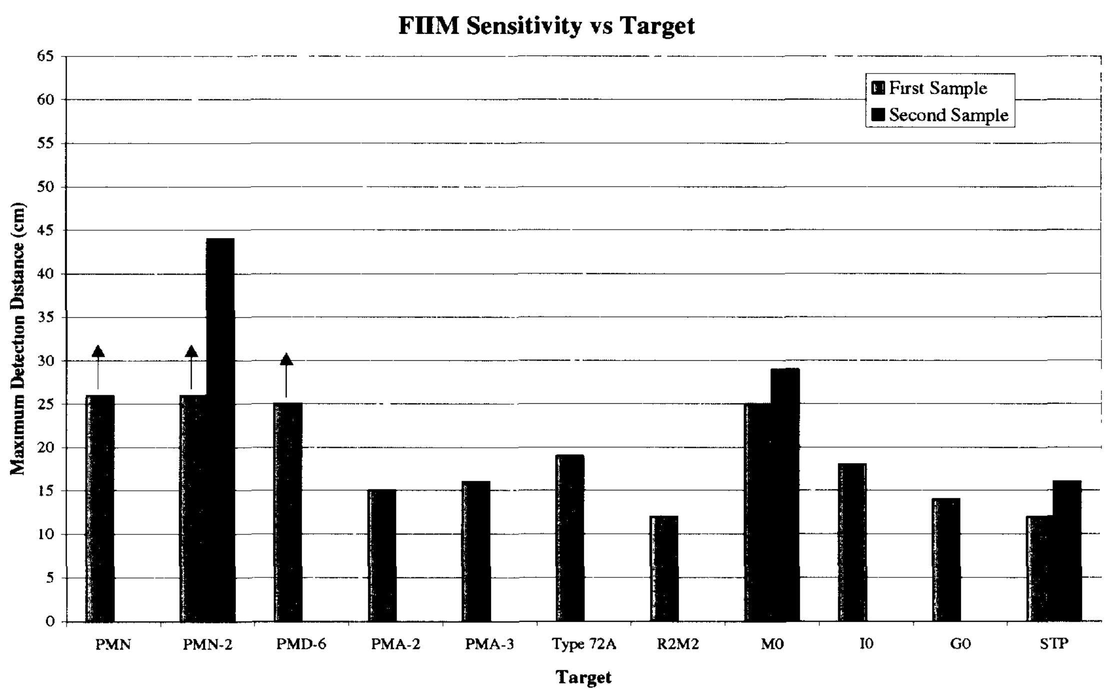

Figure 40: Maximum detection distance for all targets for the Fisher Research Impulse 10.5" detector (FIIM) Arrows indicate greater than (Section 1.5)

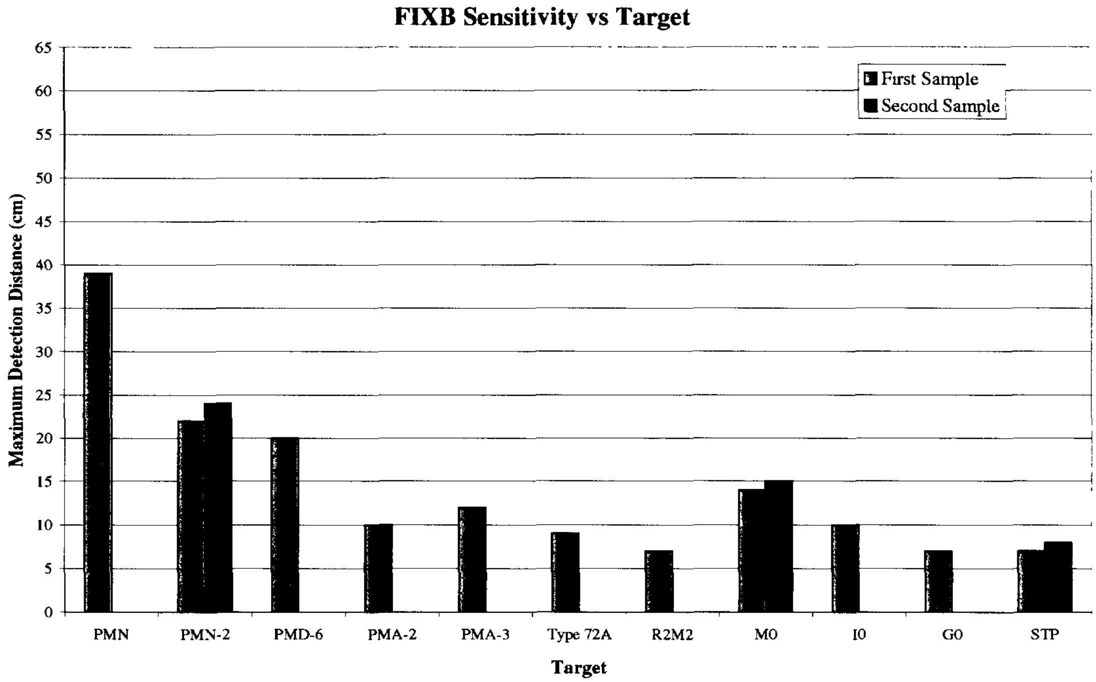

*Figure 41: Maximum detection distance for all targets for the Fisher Research 1266 XB 8" detector (**FIXB**).*

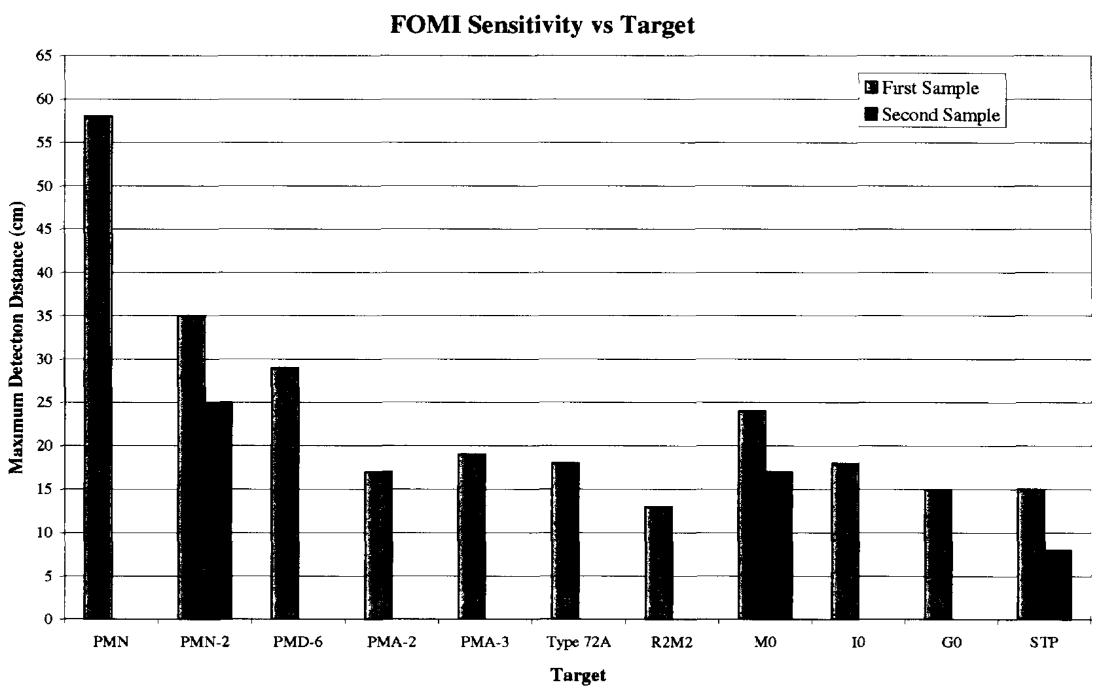

*Figure 42: Maximum detection distance for all targets for the FOERSTER Minex 2FD 4.400.01 detector (**FOMI**).*

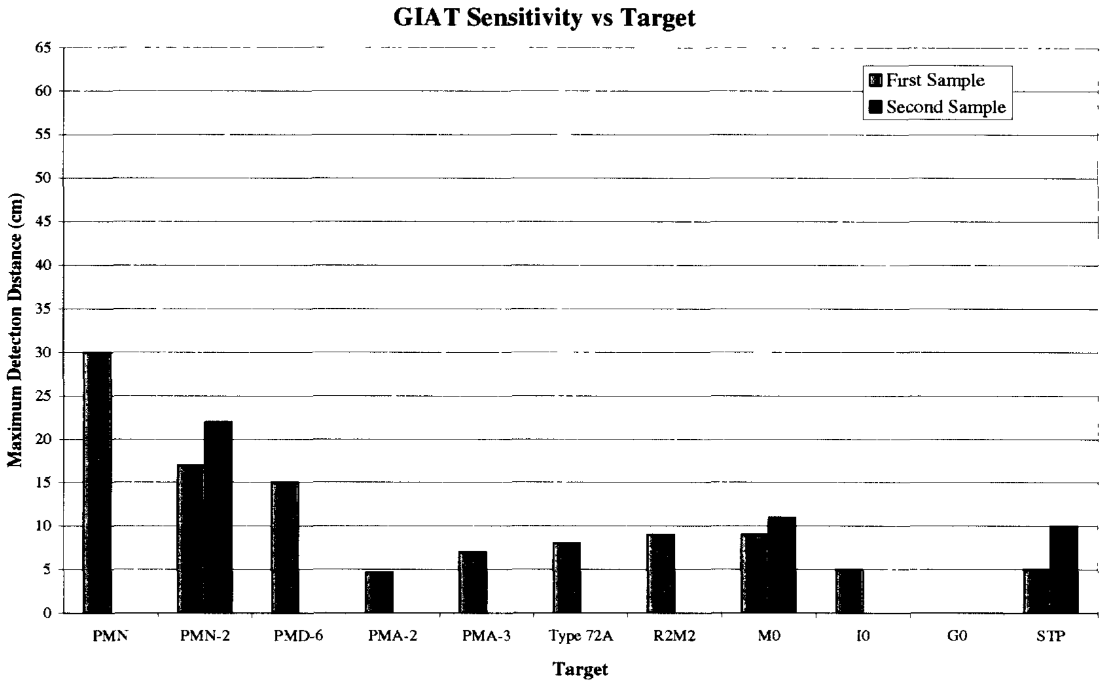

Figure 43: Maximum detection distance for all targets for the GIAT F1 detector (GIAT).

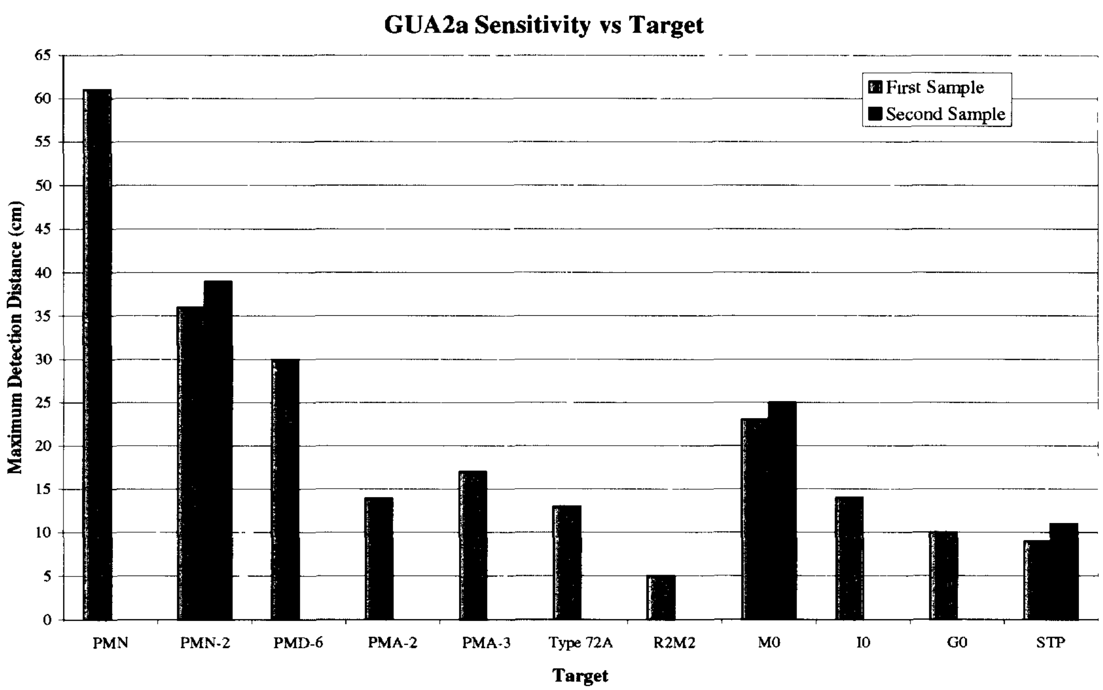

Figure 44: Maximum detection distance for all targets for the Guartel MD 2000 (round coil) detector (GUA2a).

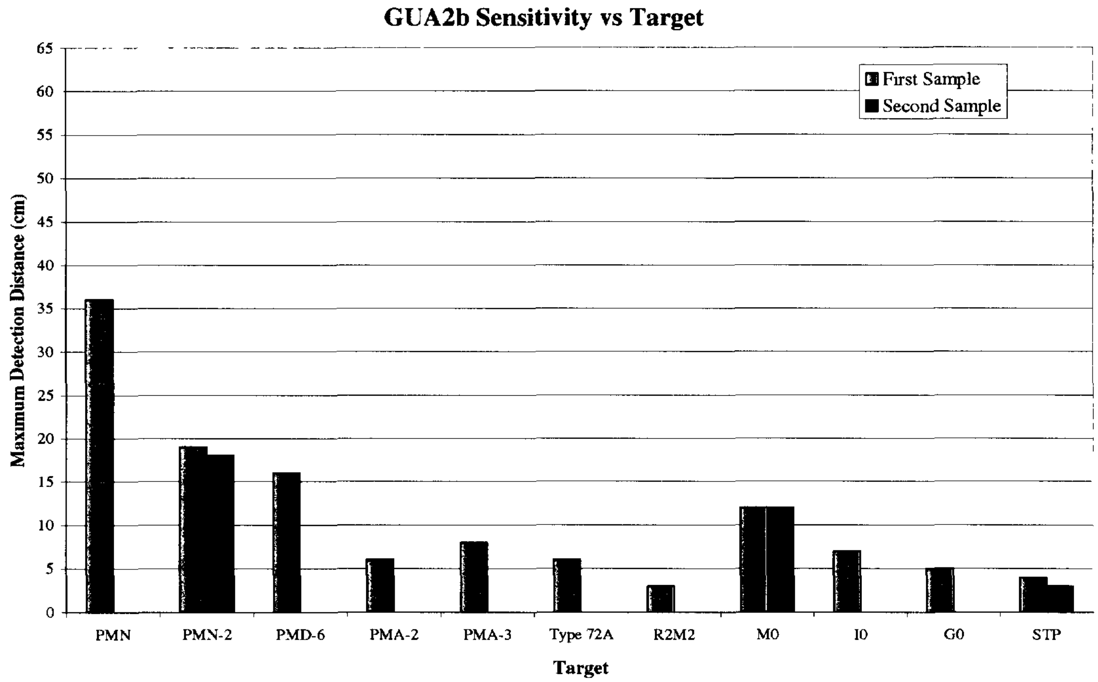

Figure 45: Maximum detection distance for all targets for the Guartel MD 2000 (long probe) detector (GUA2b).

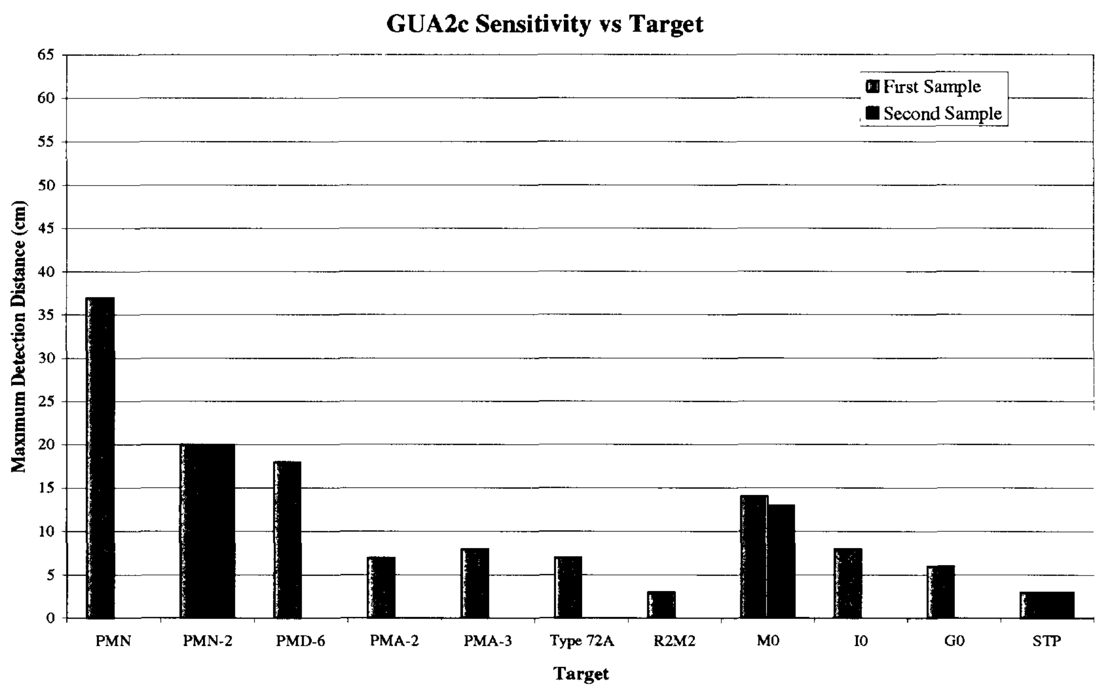

Figure 46: Maximum detection distance for all targets for the Guartel MD 2000 (small probe) detector (GUA2c).

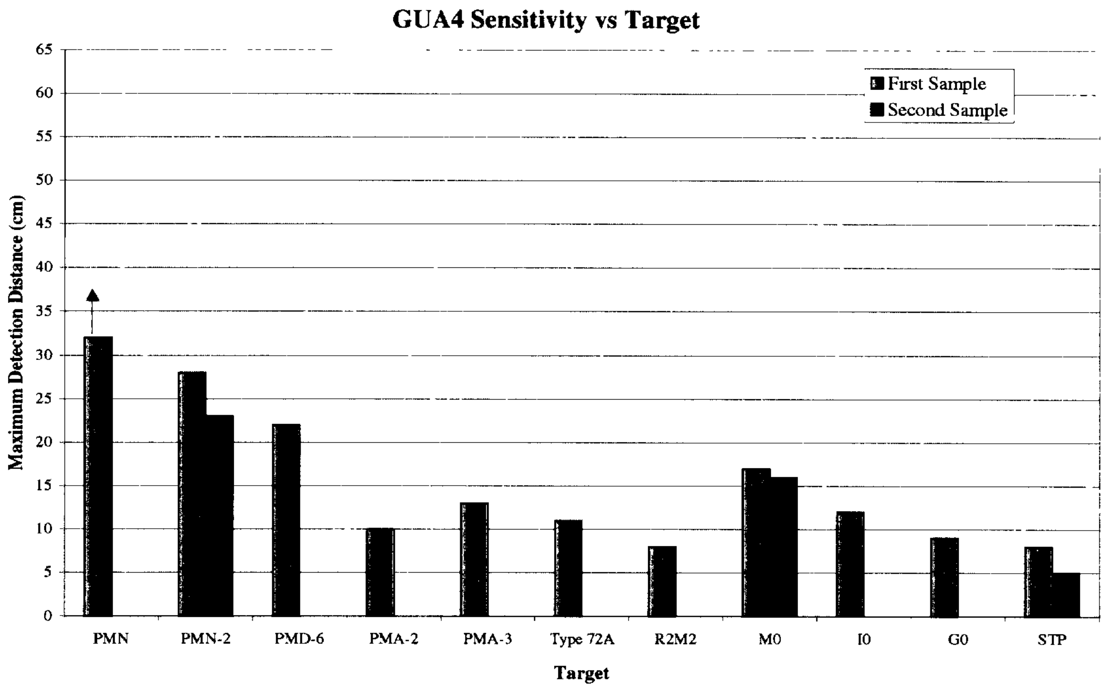

Figure 47: *Maximum detection distance for all targets for the Guartel MD 4 Detector (***GUA4***). Arrows indicate greater than (Section 1.5).*

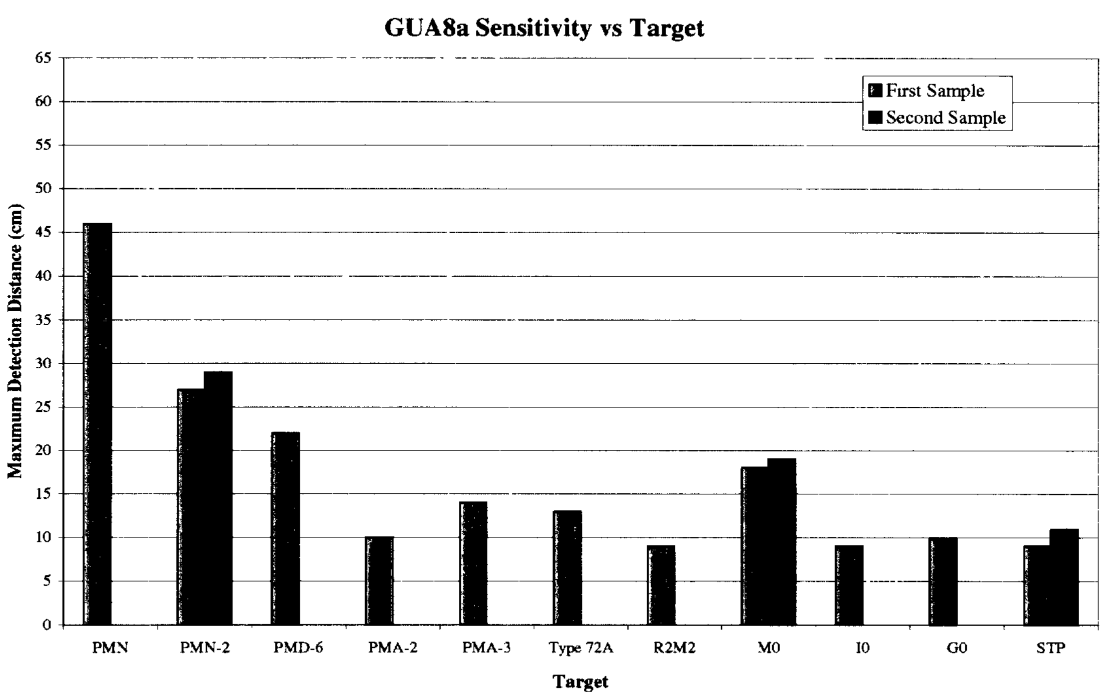

Figure 48: *Maximum detection distance for all targets for the Guartel MD 8a (round coil) detector (***GUA8a***)*

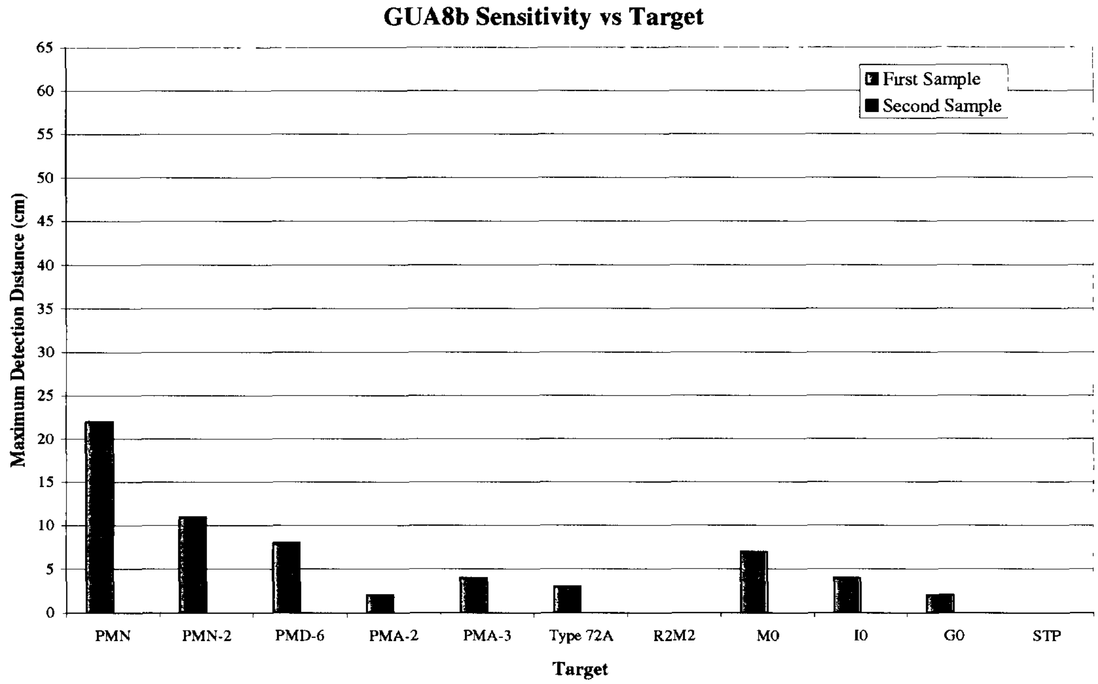

Figure 49: *Maximum detection distance for all targets for the Guartel MD 8b (oval coil) detector (GUA8b). Only one detector sample available (Section 1 7)*

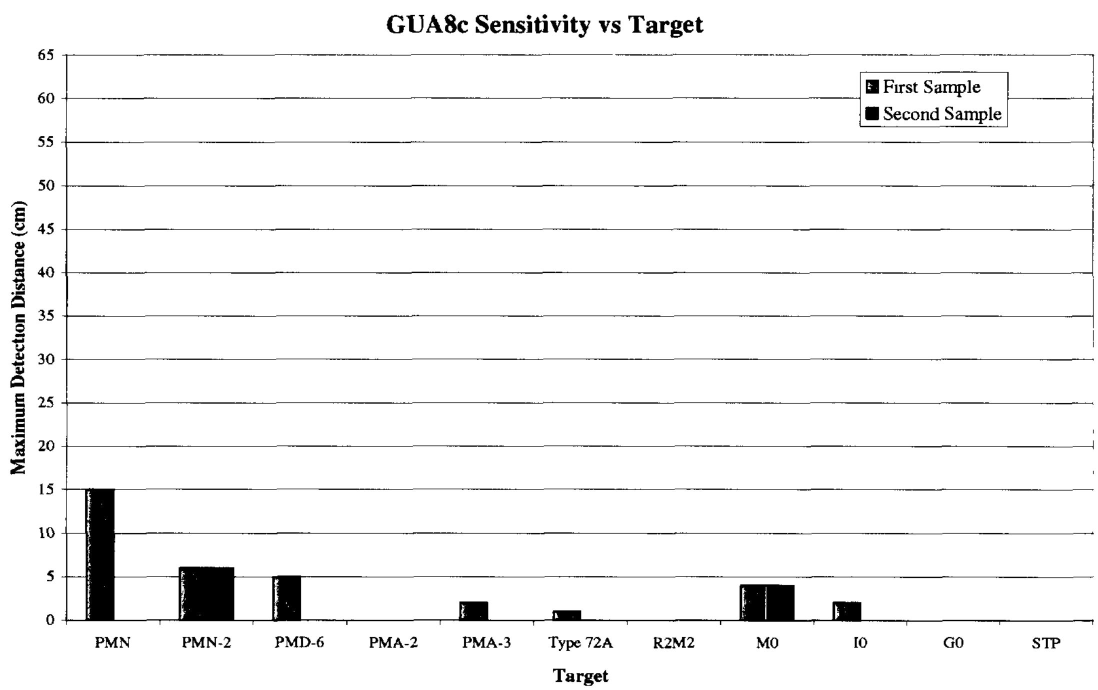

Figure 50: *Maximum detection distance for all targets for the Guartel MD 8c (probe) detector (GUA8c).*

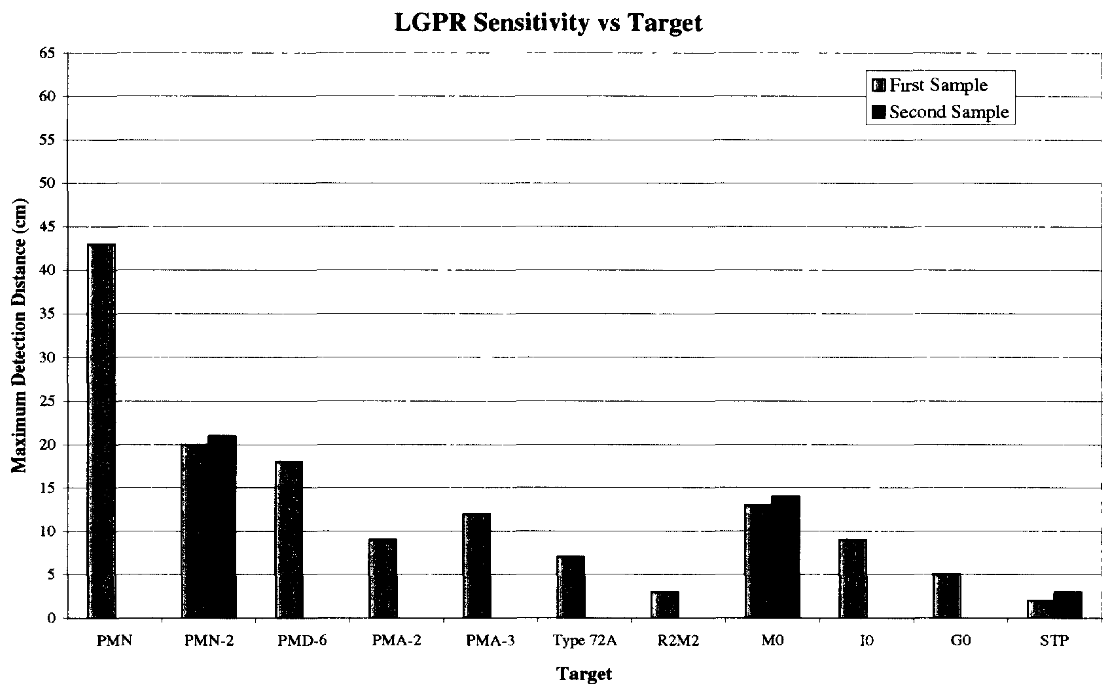

Figure 51: *Maximum detection distance for all targets for the LG Precision PRS 17 K detector (***LGPR***).*

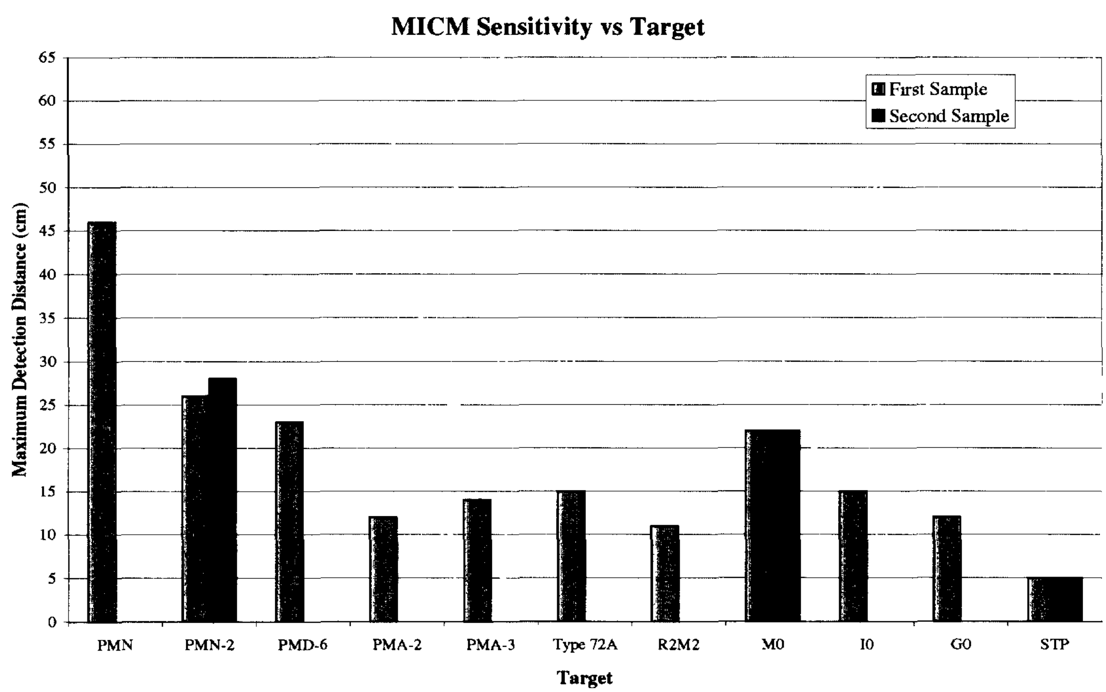

Figure 52: *Maximum detection distance for all targets for the Minelab F1A4 detector (***MICM***).*

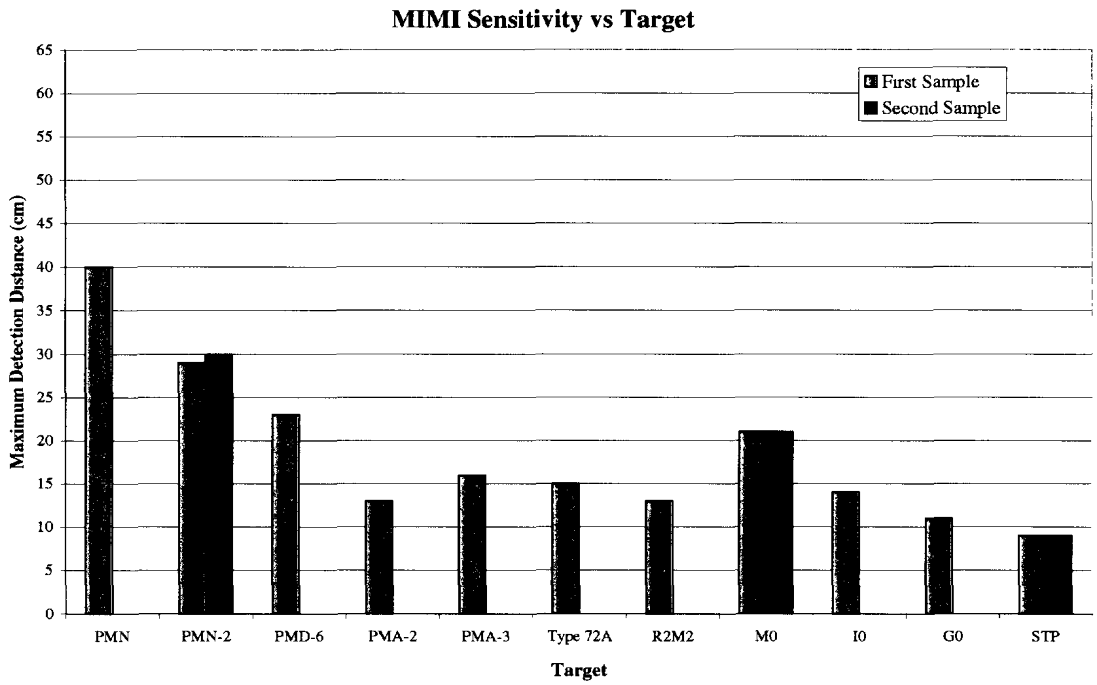

Figure 53: *Maximum detection distance for all targets for the Minelab F1A4 detector (***MIMI***).*

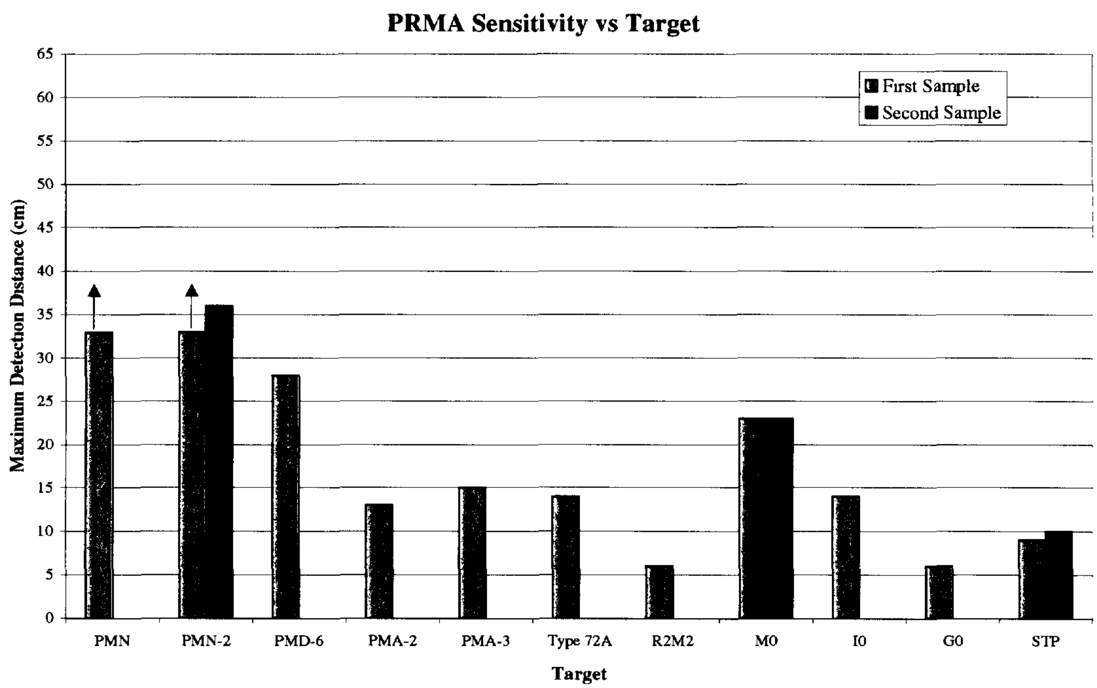

Figure 54: *Maximum detection distance for all targets for the Pro Scan Mark 2 detector (***PRMA***). Arrows indicate greater than (Section 1.5).*

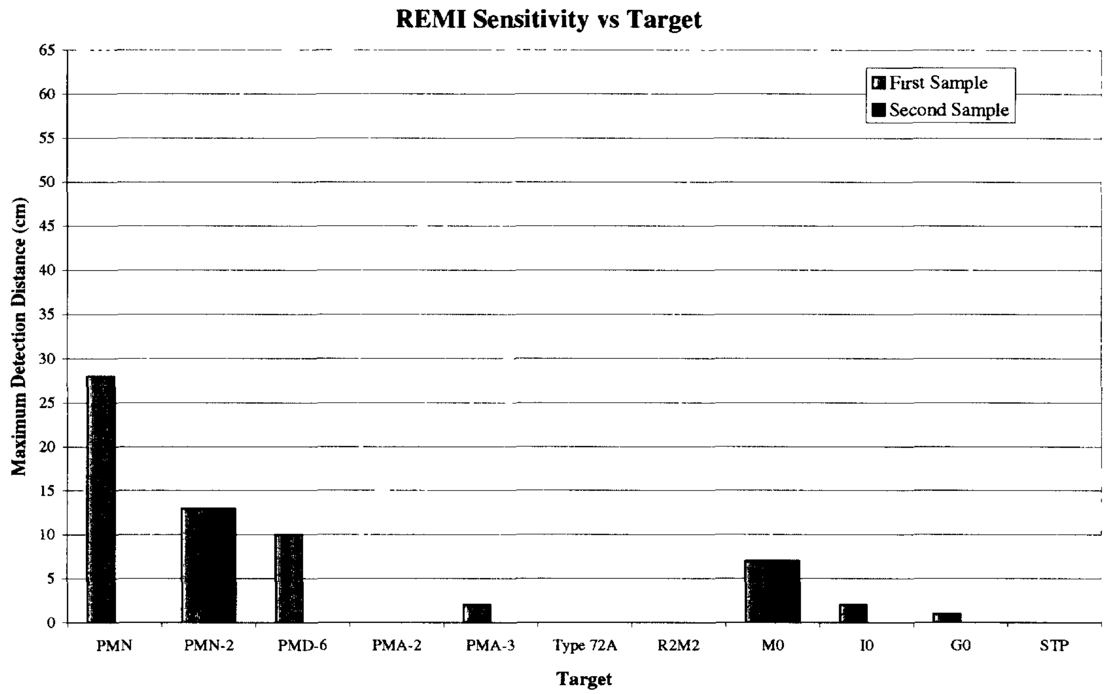

Figure 55: Maximum detection distance for all targets for the Reutech Midas PIMD detector (REMI).

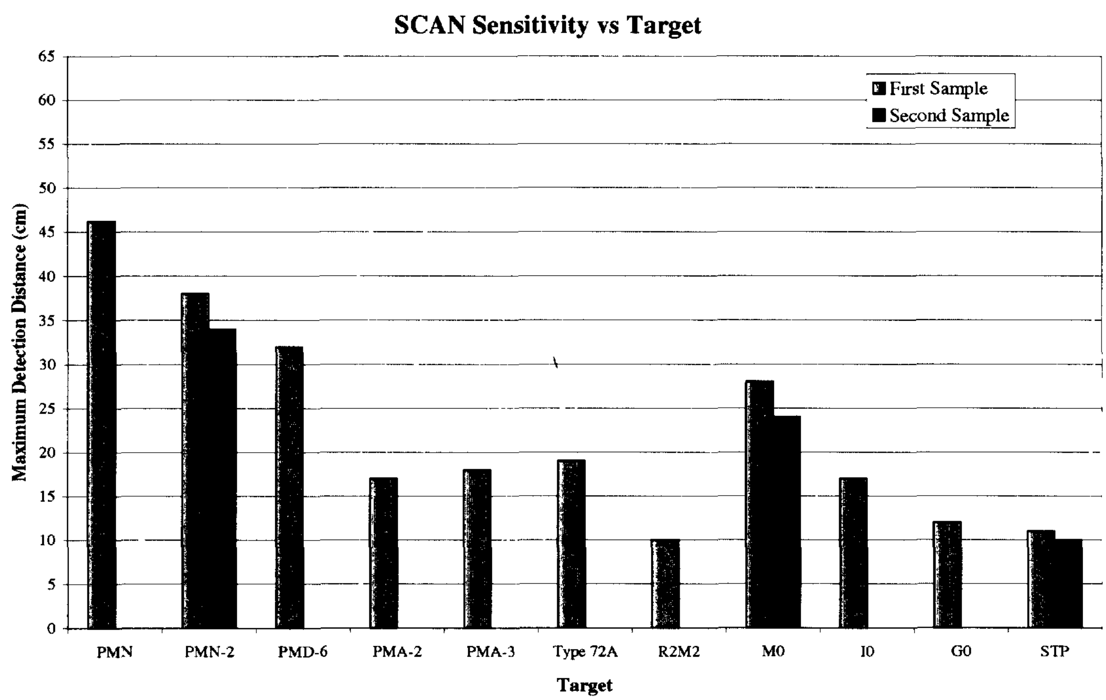

Figure 56: Maximum detection distance for all targets for the Schiebel AN19/2 detector (SCAN)

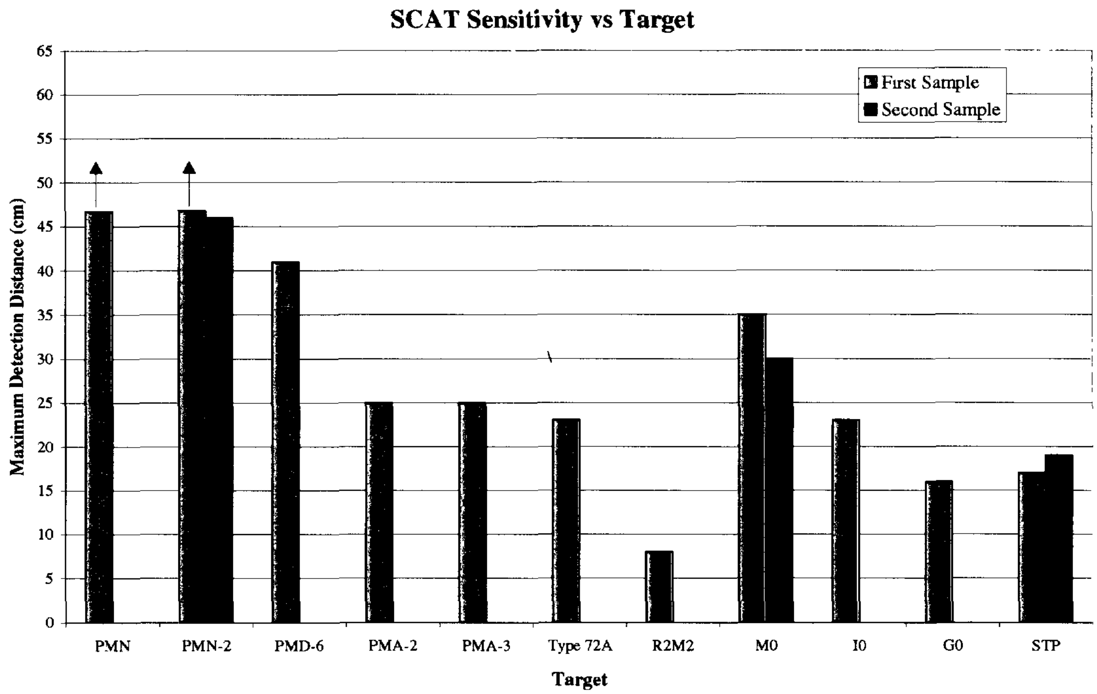

Figure 57: *Maximum detection distance for all targets for the Schiebel ATMID detector (SCAT).Arrows indicate greater than (Section 1 5).*

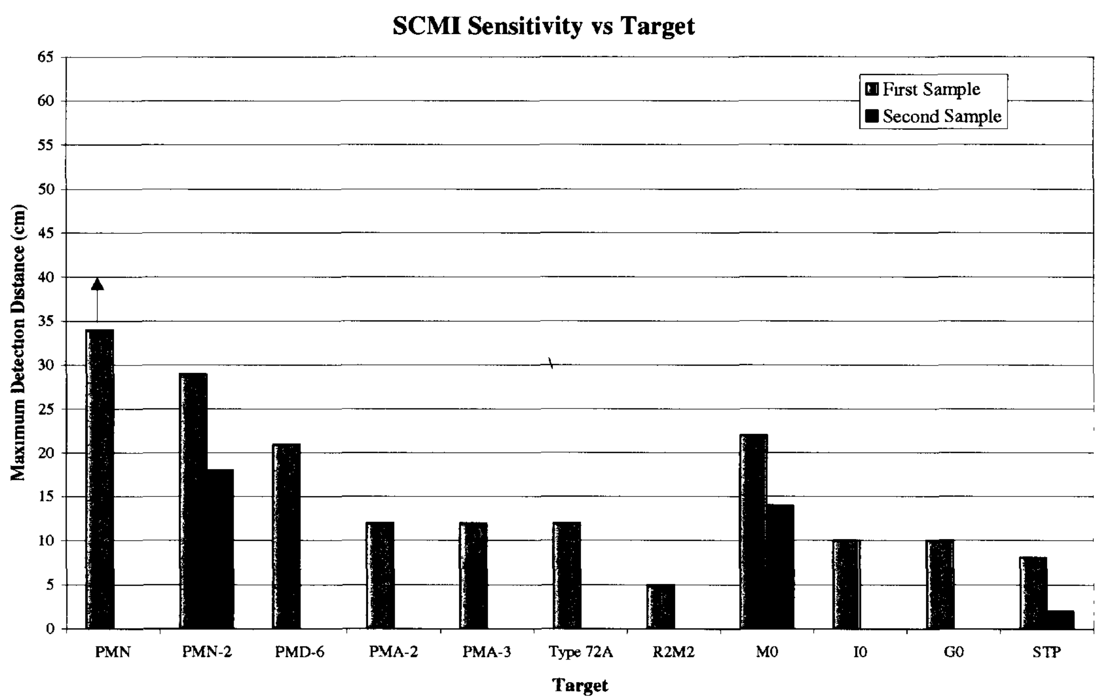

Figure 58: *Maximum detection distance for all targets for the Schiebel MIMID detector (SCMI). Arrows indicate greater than (Section 1.5).*

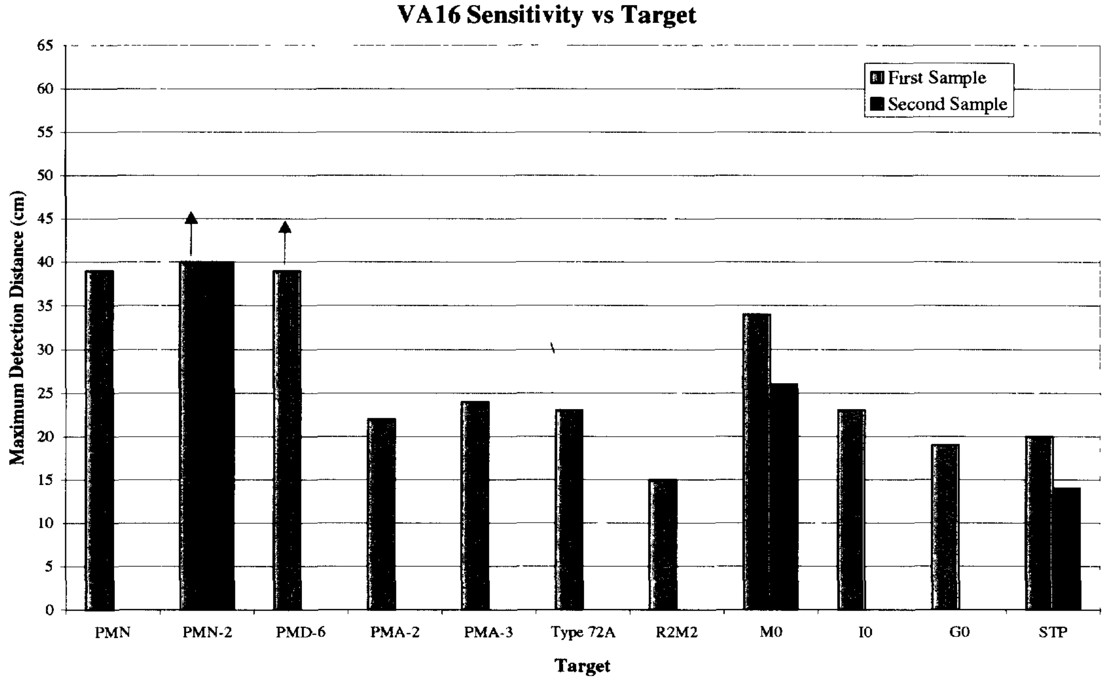

Figure 59: Maximum detection distance for all targets for the Vallon ML1620C detector (VA16). Arrows indicate greater than (Section 1.5)

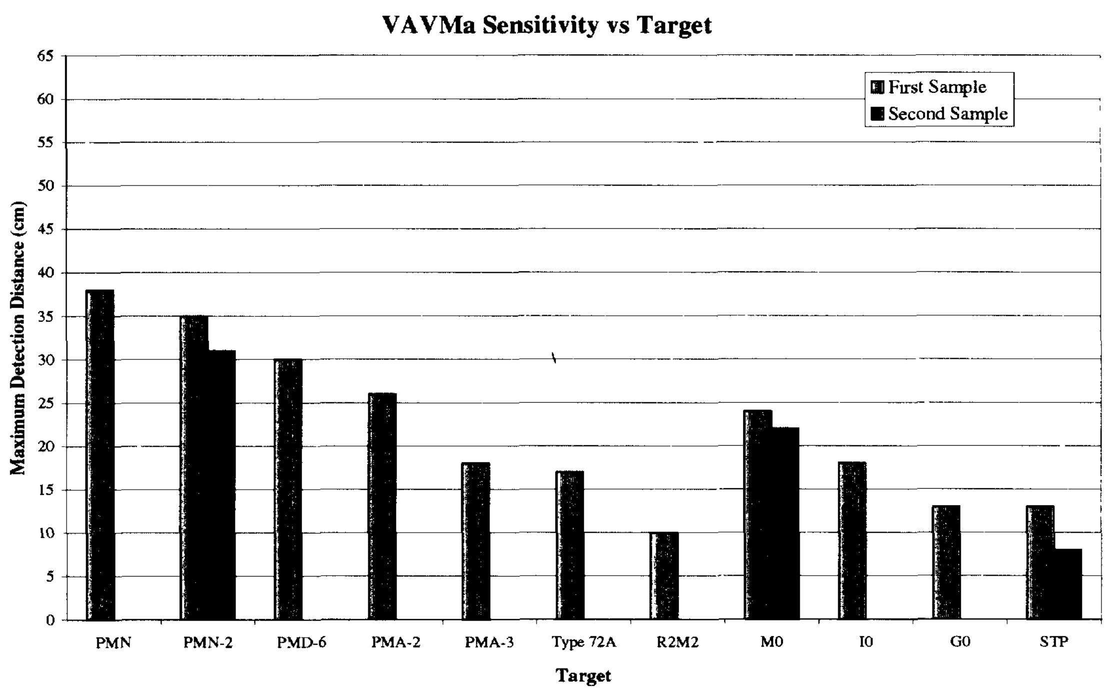

Figure 60: Maximum detection distance for all targets for the Vallon VMH2 detector (VAVMa).

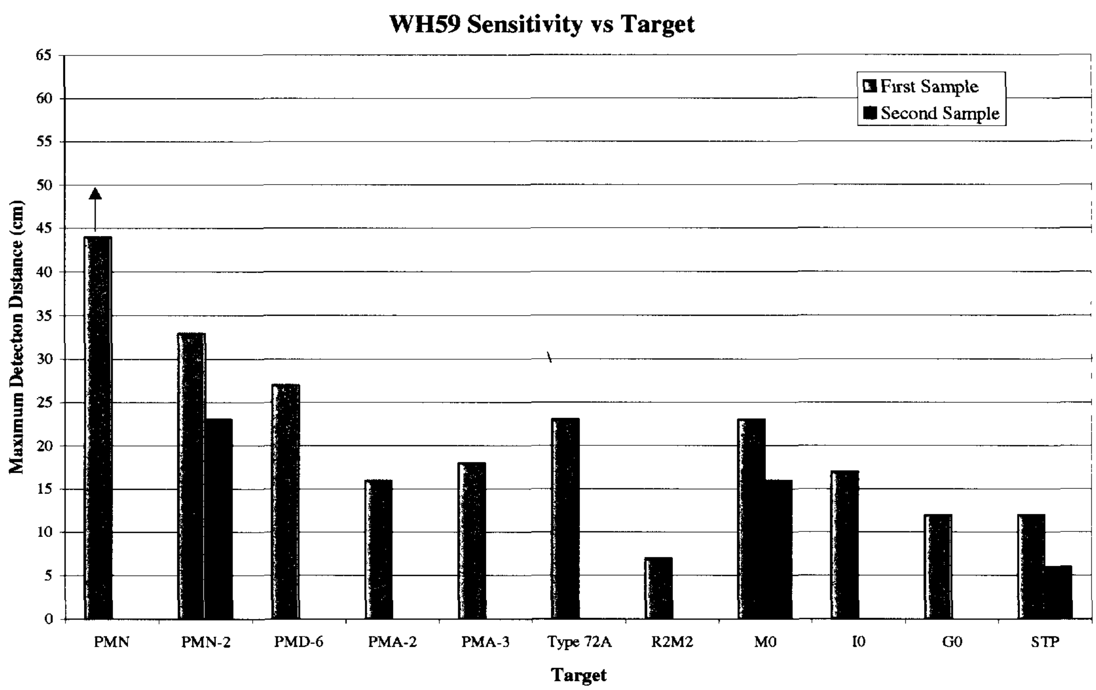

Figure 61: *Maximum detection distance for all targets for the White's Electronics 5900CB detector (**WH59**). Arrows indicate greater than (Section 1 5)*

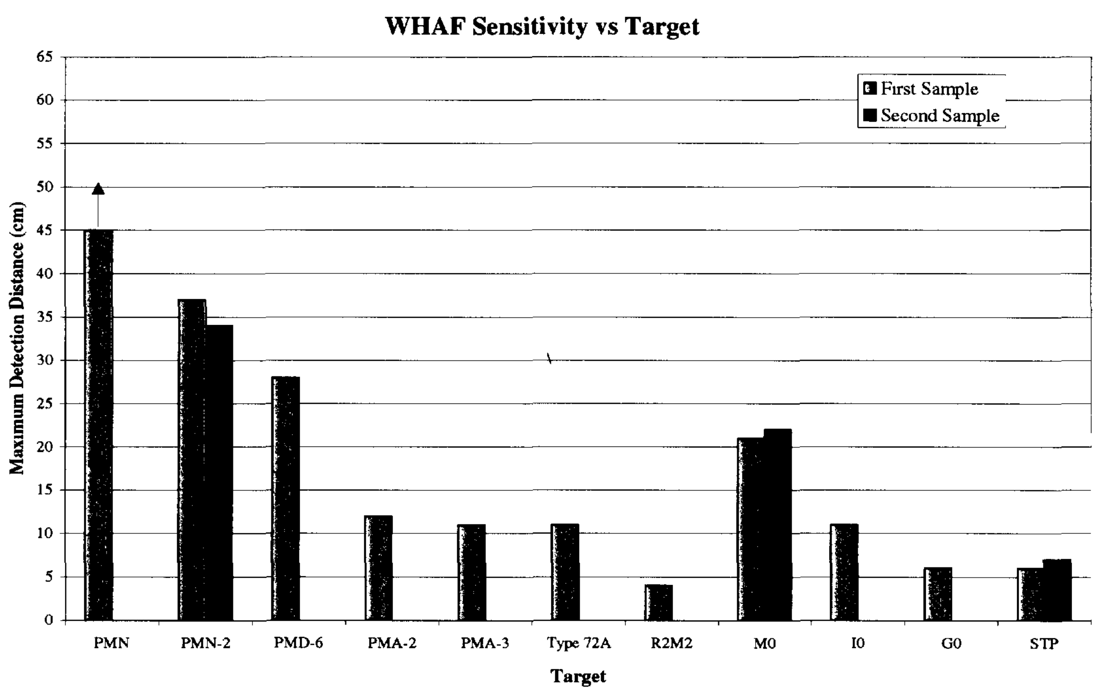

Figure 62: *Maximum detection distance for all targets for the White's Electronics NATO MD AE-108 detector (**WHAF**). Arrows indicate greater than (Section 1.5).*

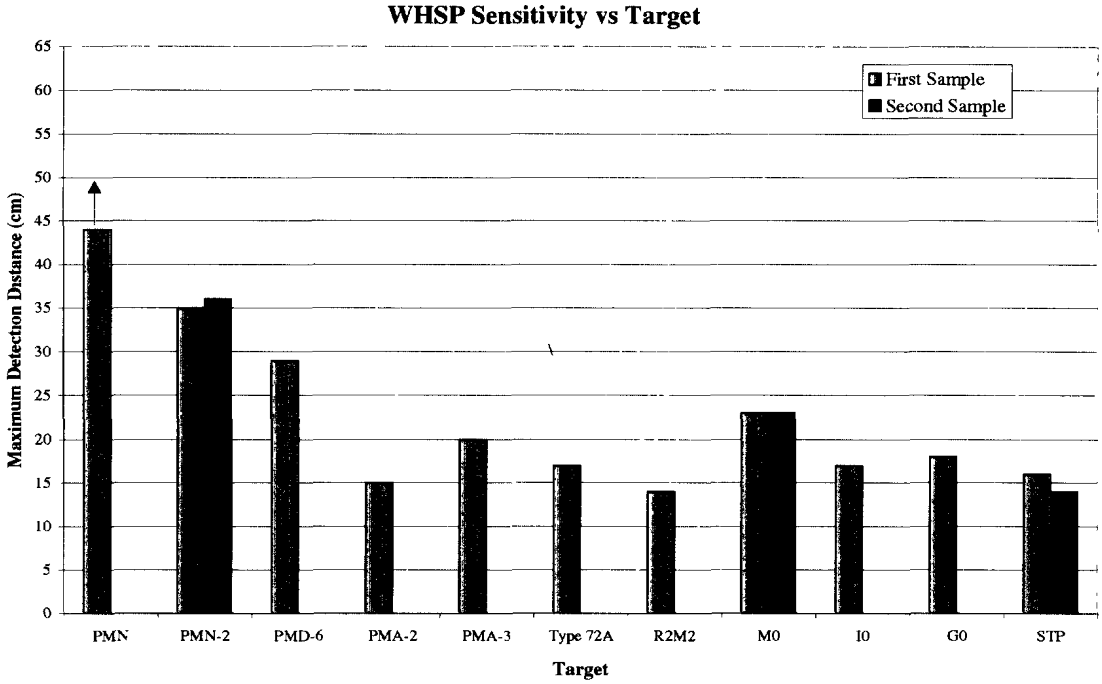

Figure 63: Maximum detection distance for all targets for the White's Electronics Spectrum XLT detector (WHSP). Arrows indicate greater than (Section 1.5).

7. Scan Profile Test

The signal produced by a given target in a detector depends on the target's location on a plane parallel to the detector head. In other words, how well a buried target is detected will depend significantly on what part of the search head is scanned over it. It is very important to characterize this aspect of sensitivity variation in order to assess the field performance of a detector as this data can guide the degree of overlap needed between consecutive scans to ensure acceptably uniform coverage.

The purpose of this test was to determine the scan profile or "footprint" of a detector. The footprint is defined as the variation of sensitivity to a target as a function of its position with respect to the sensor head. In this report, a quantity proportional to the energy of the recorded audio signal (Section 1.4) as a function of the two-dimensional position of the detector head over the target is taken to represent the footprint. The relationship of this signal amplitude map to detectability of a target is complex and was not explored. The target $\mathbf{M_0}$ in vertical orientaion was used for this test and only one sample of each detector was measured. The size and shape of the footprint may differ significantly depending not only on the detector but also on the target, its size, orientation and depth. To provide an indication of the variation in the size of the footprint with depth, data were recorded corresponding to three different target depths:

(a) target 2 cm closer to the sensor head than the maximum detection distance for the

target;

(b) target at 2 cm from the sensor head; and

(c) target at a location half-way between positions (a) and (b).

For some detectors, because of small the maximum detection distance for the target, fewer than three depths were used.

Footprint information for each detector is presented as colour maps in a pair of figures each using a different data scaling (Figures 64 to 120). In the figures using a "locked" scale (top of page), the entire range of data corresponding to the three target depths is normalized to the range 0-1 and mapped using the colour key shown beside the figure. In the figures using an "unlocked" scale (bottom of page), data corresponding to each depth is separately normalized to the range 0-1 and plotted using the colour key shown beside the figure. The locked scale presentations should preserve the relative signal strength for the three target depths, but may not register the weak signal for the deepest target in some cases. The unlocked scale, on the other hand, does not preserve the relative signal strength for the three target depths, but enhances the contrast at each depth, revealing structures not seen in the other presentation in some cases.

The results from the Scan Profile Test would help the user understand the general shape of the effective "detection volume" of each detector. The figures show that the detector footprint generally becomes smaller as the target depth increases, resulting in a cone-shaped "detection volume". For the small target, typical of minimum-metal mines, this general trend of shrinking footprint with depth was observed for all the detectors tested. This finding is contrary to claims by some manufacturers. Although our data would help the user adjust his training and Standard Operating Procedures (SOPs), in order to make quantitative use of footprint data they should be measured more precisely and for a number of targets of interest.

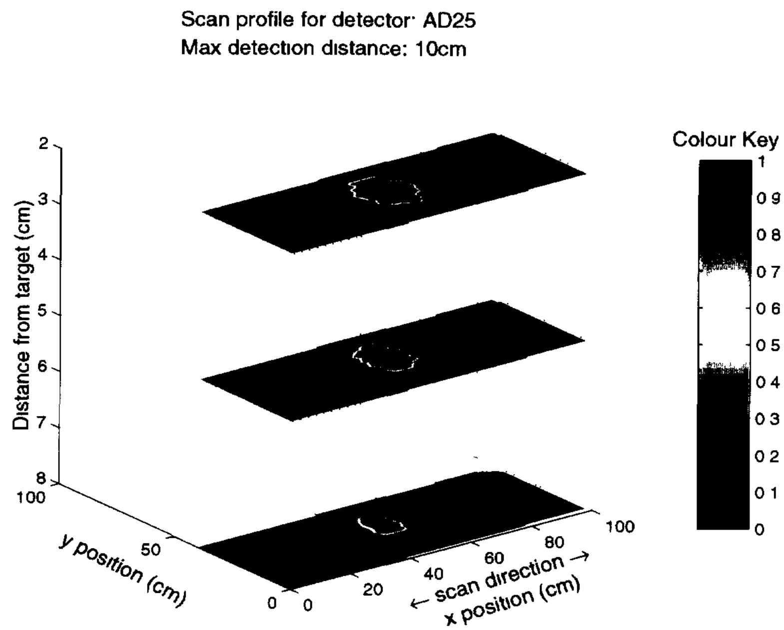

Figure 64: *Scan profiles for the Adams Electronics 2500 detector (***AD25***). Locked scale.*

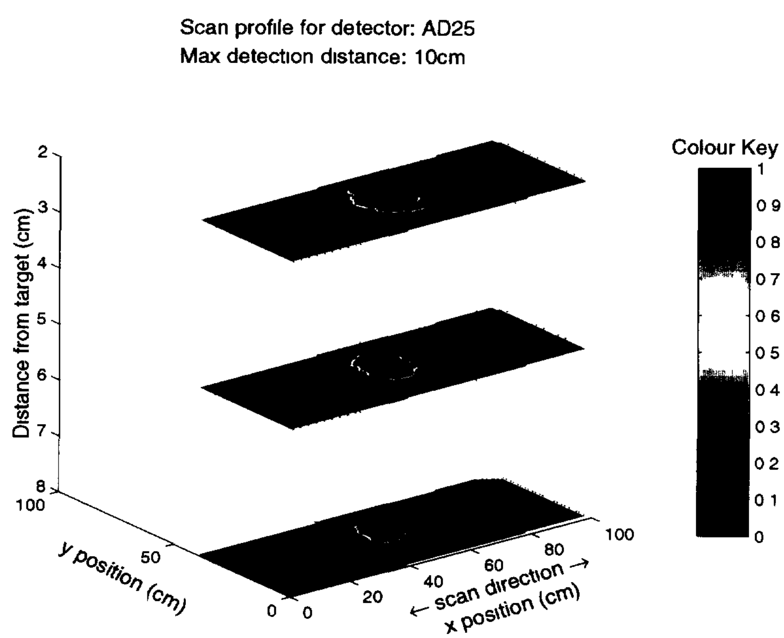

Figure 65: *Scan profiles for the Adams Electronics 2500 detector (***AD25***). Unlocked scale.*

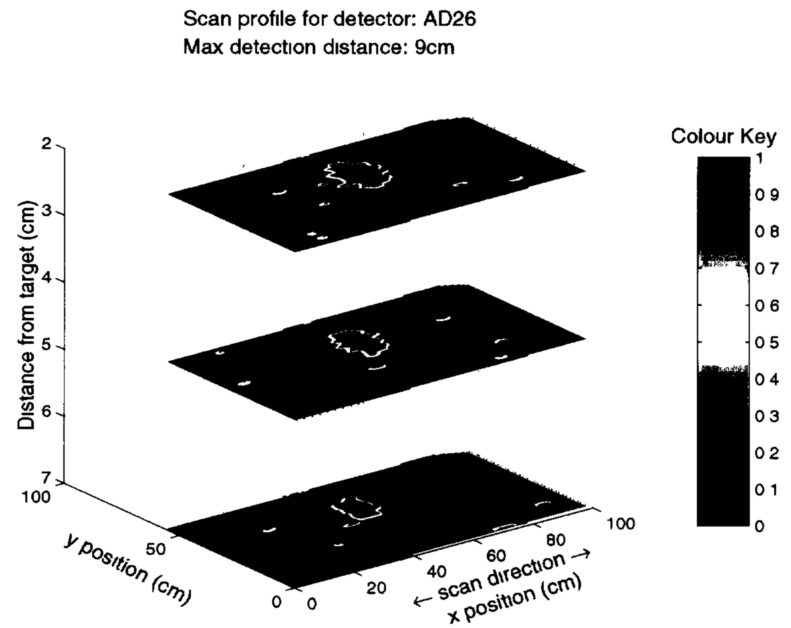

Figure 66: *Scan profiles for the Adams Electronics 2600 detector (AD26). Locked scale.*

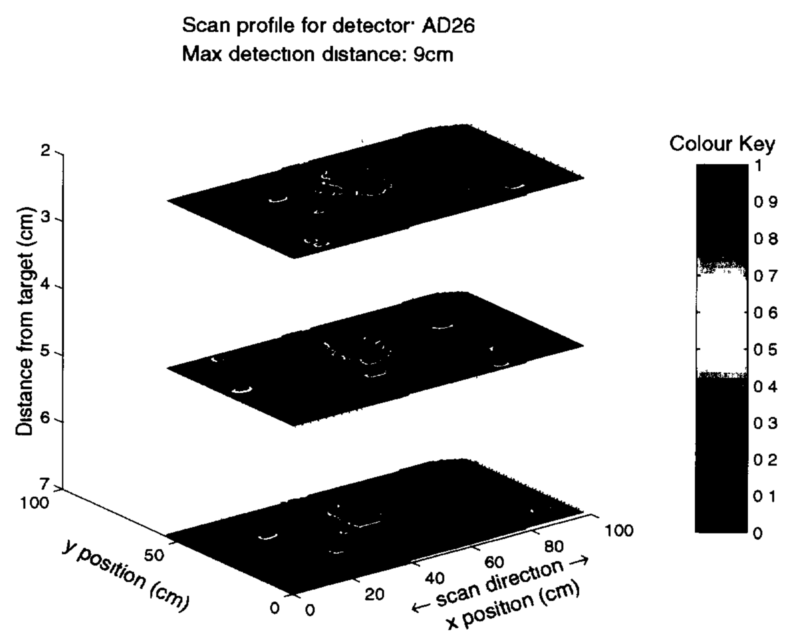

Figure 67: *Scan profiles for the Adams Electronics 2600 detector (AD26). Unlocked scale.*

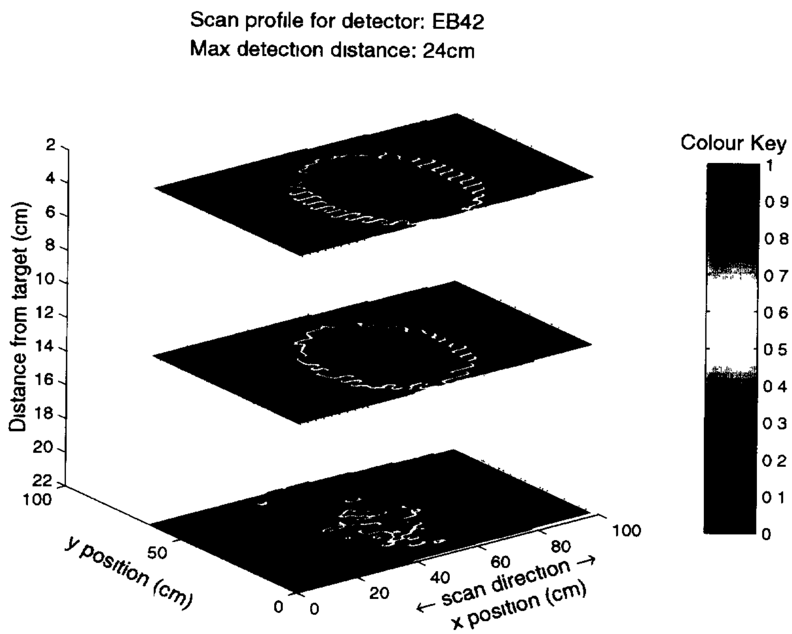

Figure 68: Scan profiles for the Ebinger EBEX 420GC detector (EB42) Locked scale

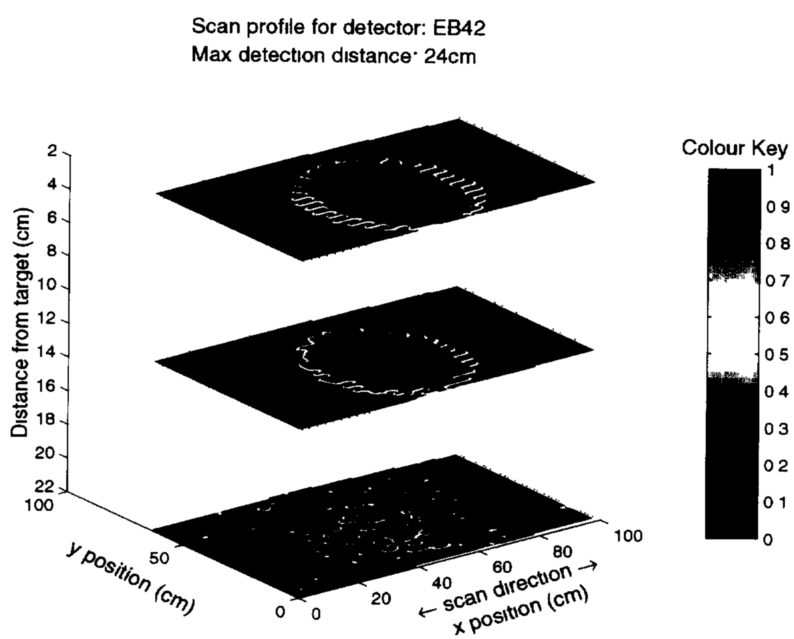

Figure 69: Scan profiles for the Ebinger EBEX 420GC detector (EB42). Unlocked scale.

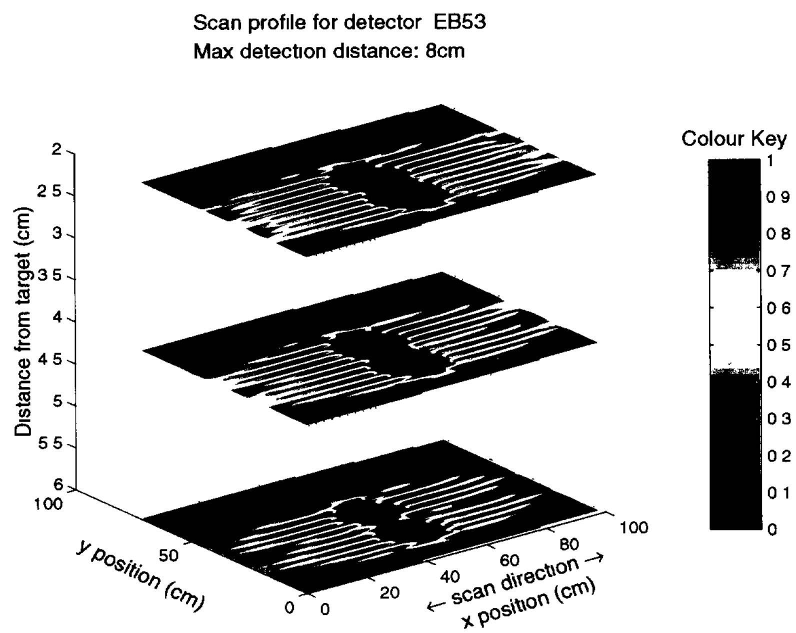

Figure 70: *Scan profiles for the Ebinger EBEX 535 detector (EB53). Locked scale.*

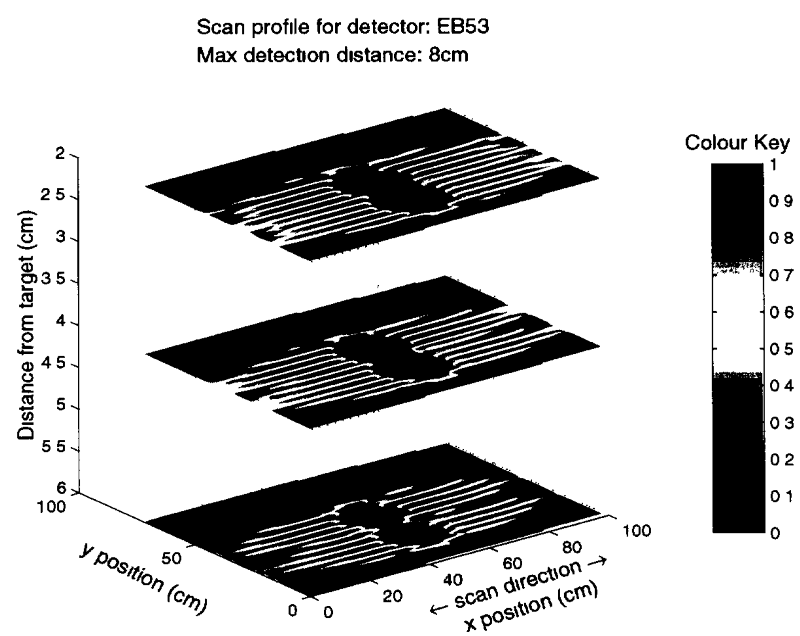

Figure 71: *Scan profiles for the Ebinger EBEX 535 detector (EB53). Unlocked scale.*

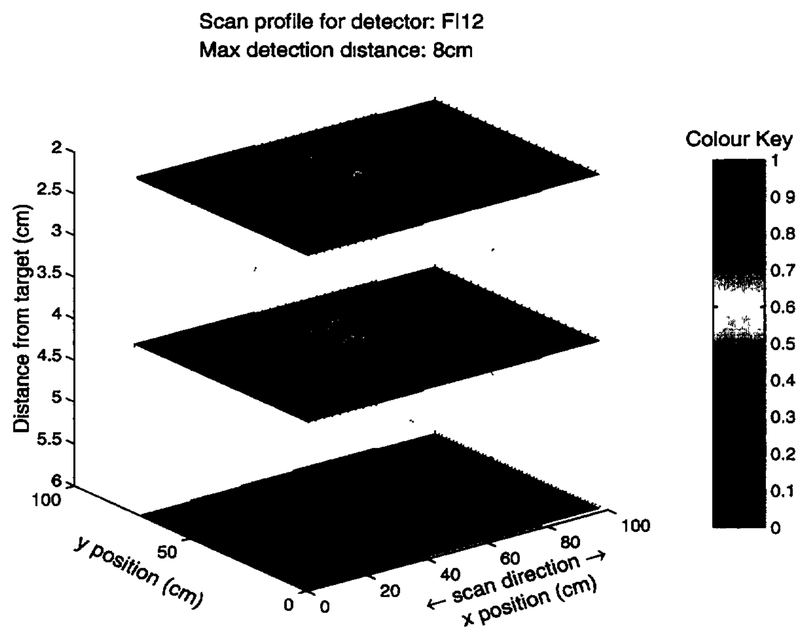

Figure 72: *Scan profiles for the Fisher Research 1235X detector (FI12). Locked scale.*

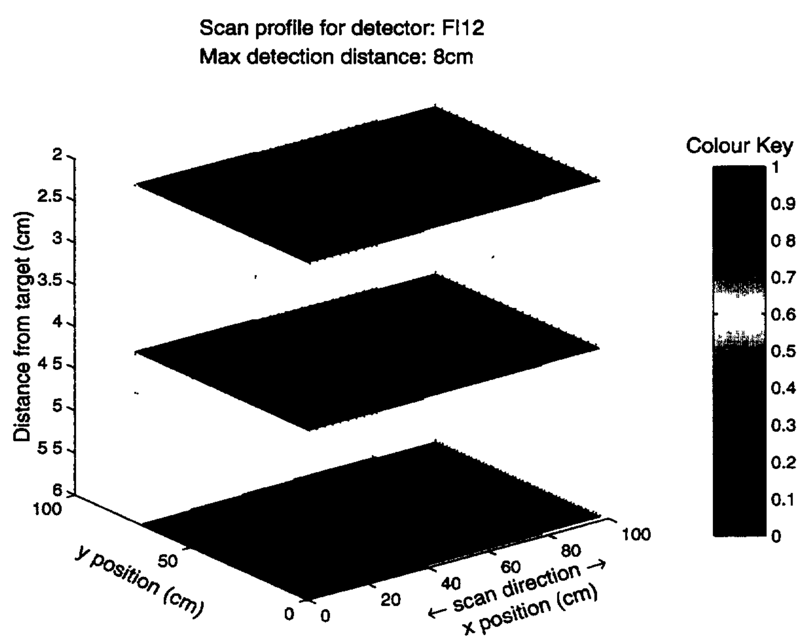

Figure 73: *Scan profiles for the Fisher Research 1235X detector (FI12). Unlocked scale.*

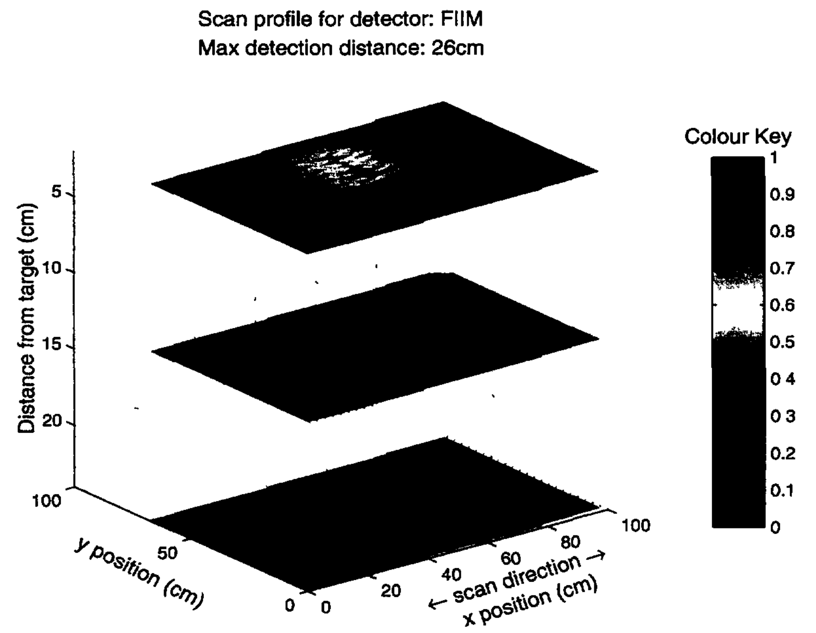

***Figure 74:** Scan profiles for the Fisher Research Impulse 10.5" detector (FIIM). Locked scale.*

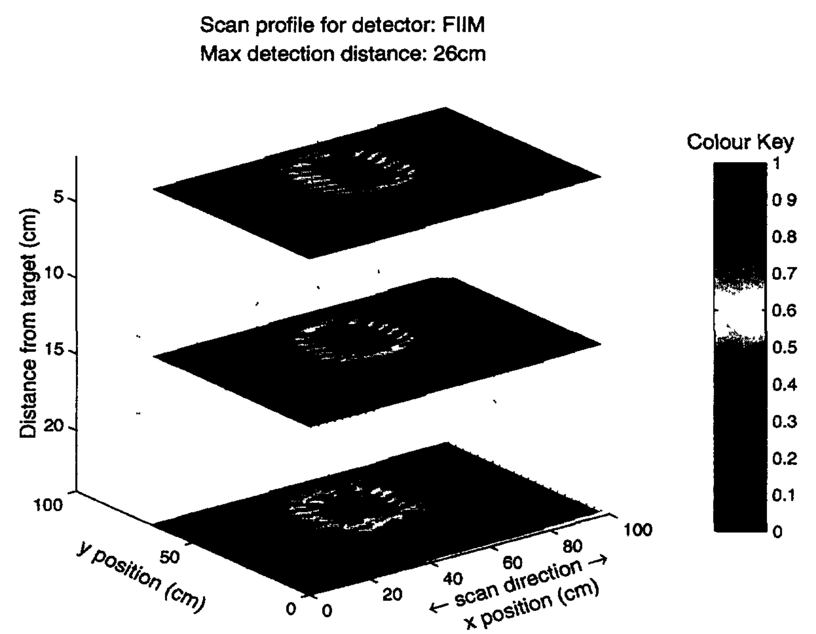

***Figure 75:** Scan profiles for the Fisher Research Impulse 10.5" detector (FIIM). Unlocked scale.*

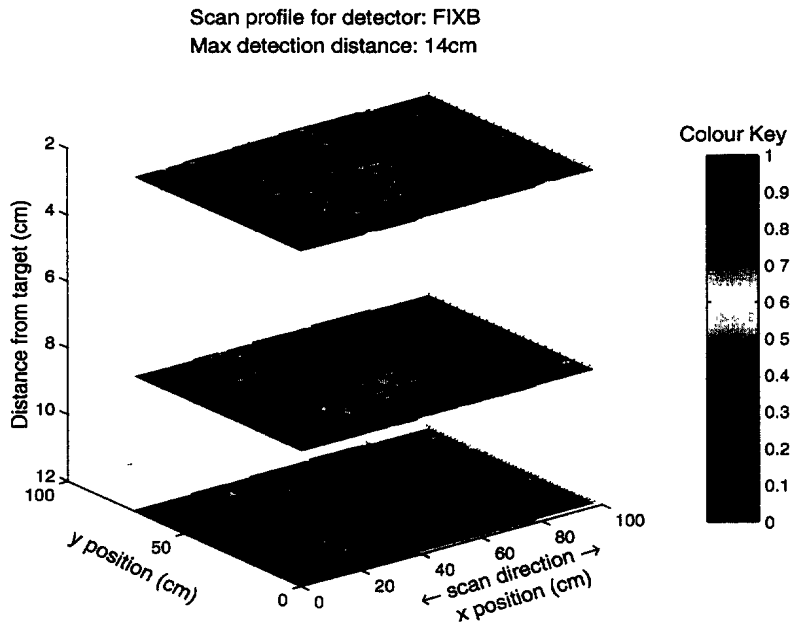

Figure 76: *Scan profiles for the Fisher Research 1266 XB 8" detector (**FIXB**). Locked scale.*

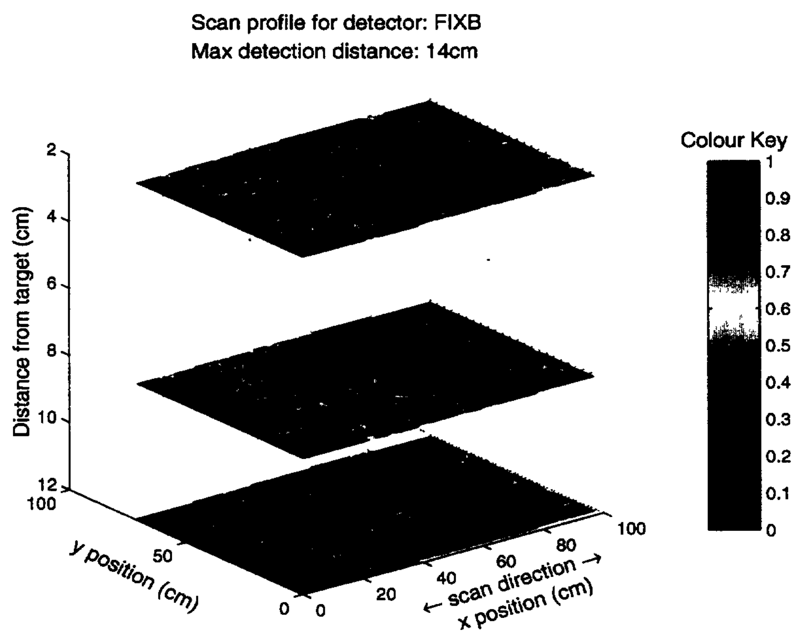

Figure 77: *Scan profiles for the Fisher Research 1266 XB 8" detector (**FIXB**). Unlocked scale.*

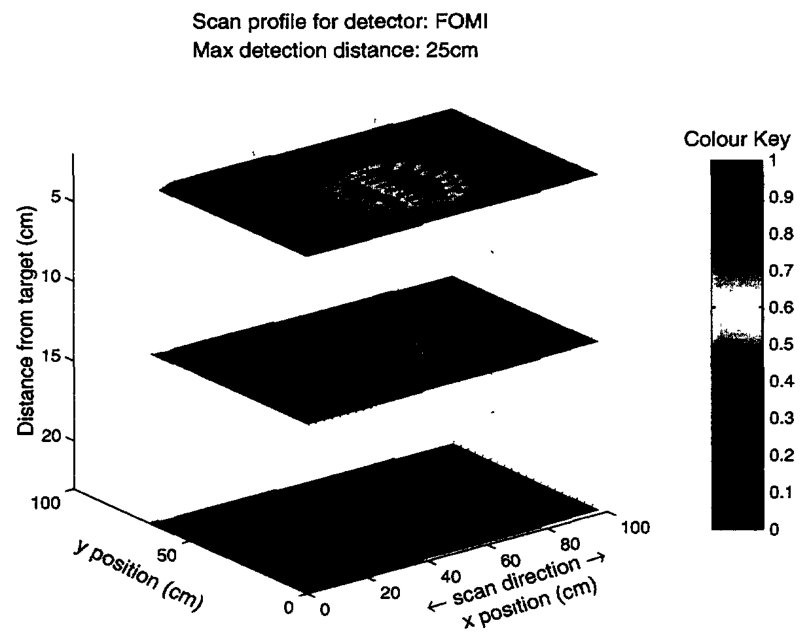

Figure 78: Scan profiles for the FOERSTER Minex 2FD 4.400.01 detector (FOMI). Locked scale.

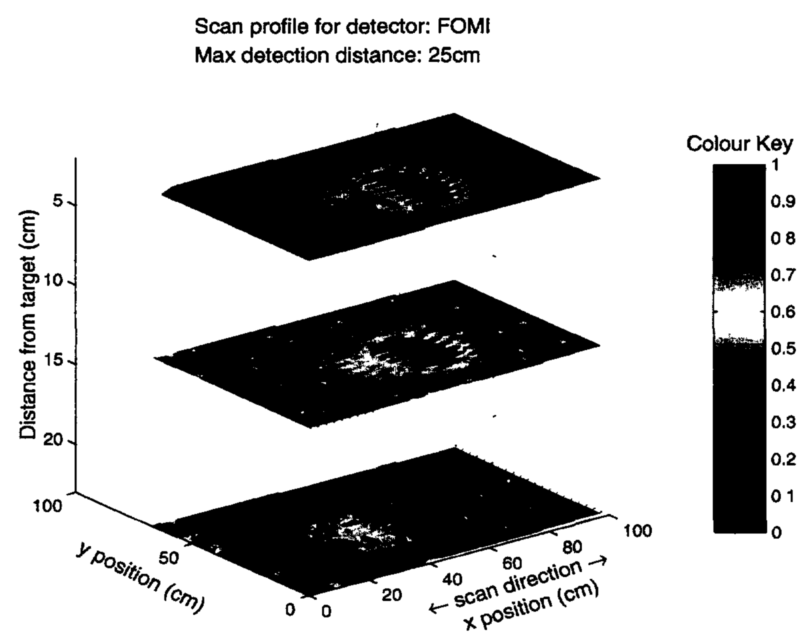

Figure 79: Scan profiles for the FOERSTER Minex 2FD 4.400.01 detector (FOMI). Unlocked scale.

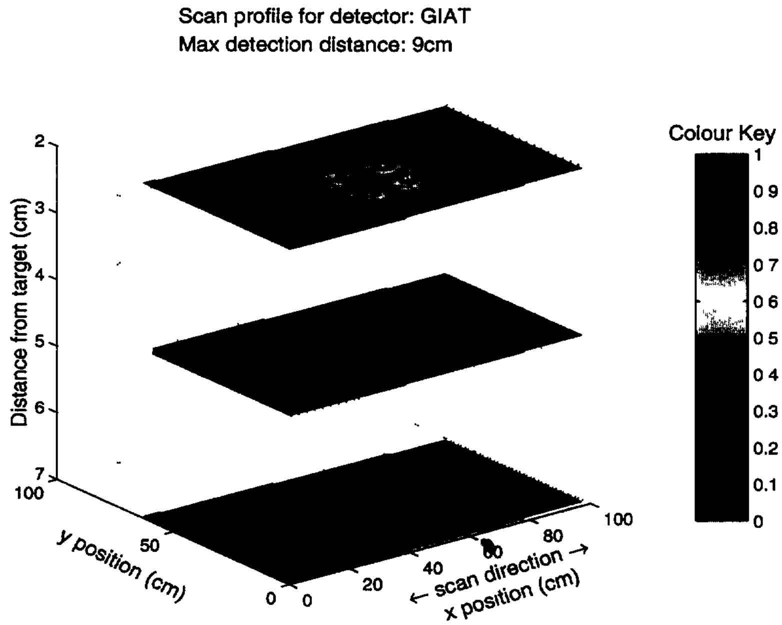

***Figure 80:** Scan profiles for the GIAT F1 detector (GIAT). Locked scale.*

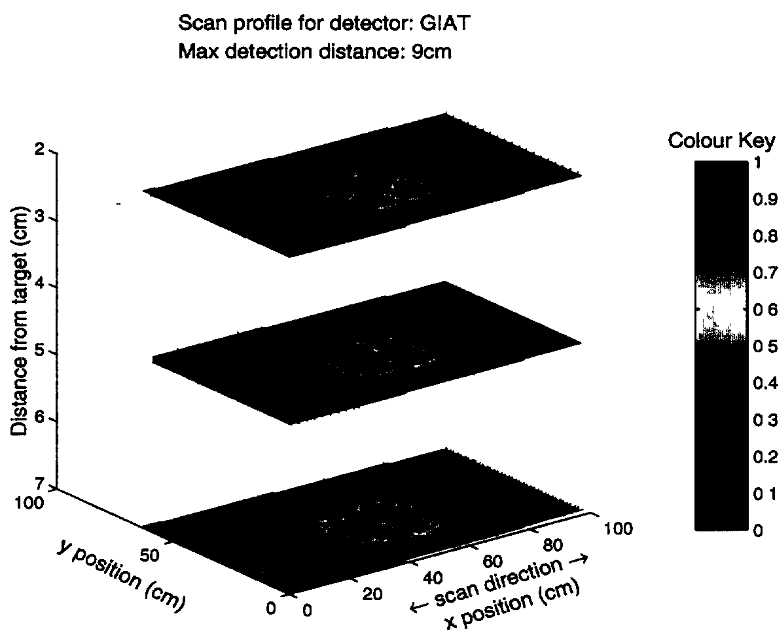

***Figure 81:** Scan profiles for the GIAT F1 detector (GIAT). Unlocked scale.*

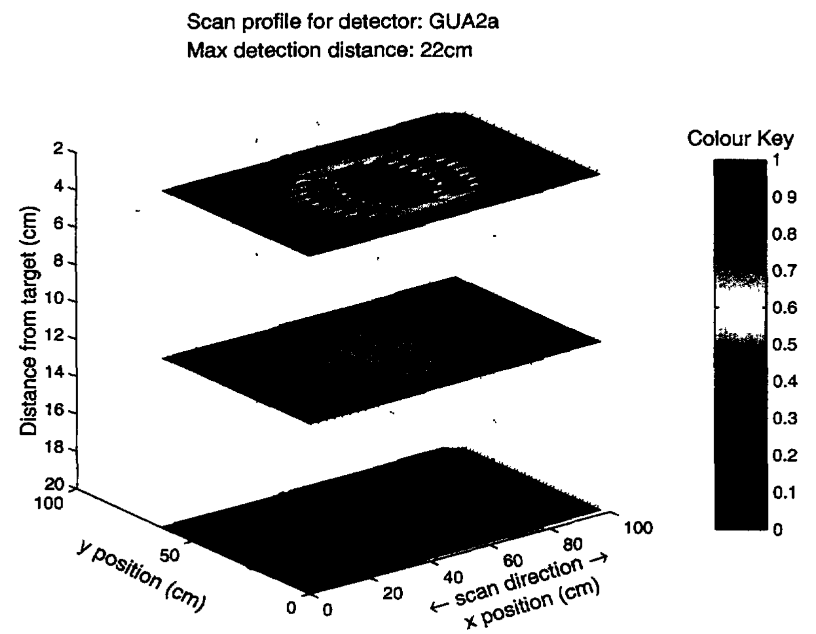

Figure 82: *Scan profiles for the Guartel MD 2000 (round coil) detector (**GUA2a**). Locked scale.*

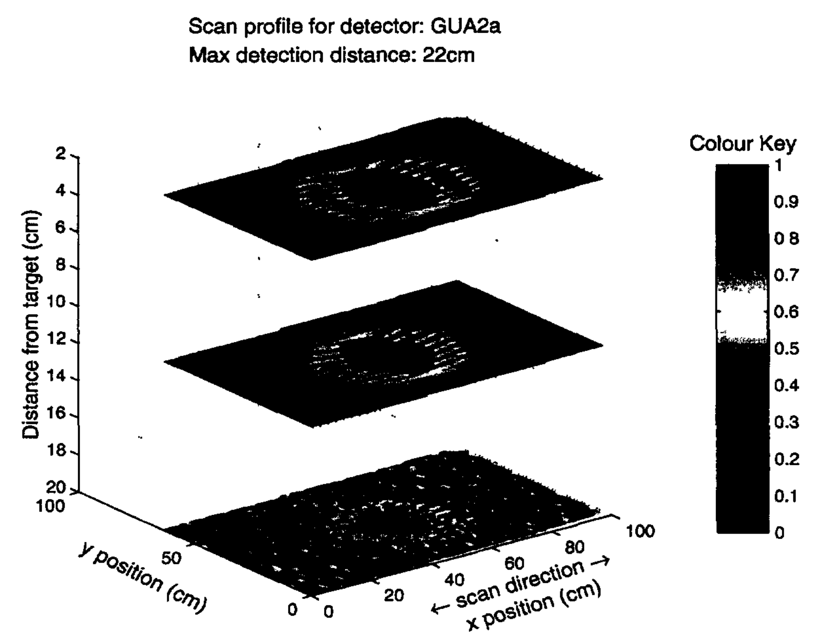

Figure 83: *Scan profiles for the Guartel MD 2000 (round coil) detector (**GUA2a**). Unlocked scale.*

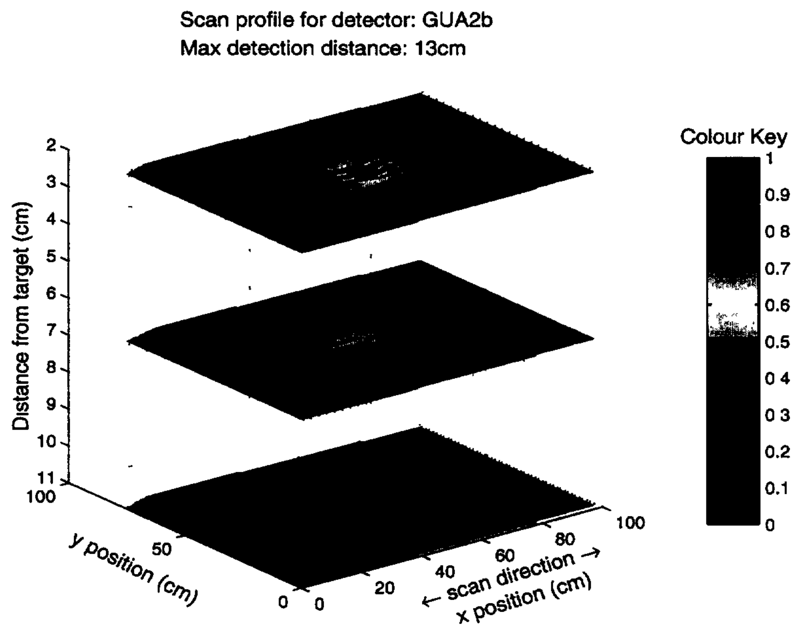

Figure 84: *Scan profiles for the Guartel MD 2000 (long probe) detector (GUA2b). Locked scale.*

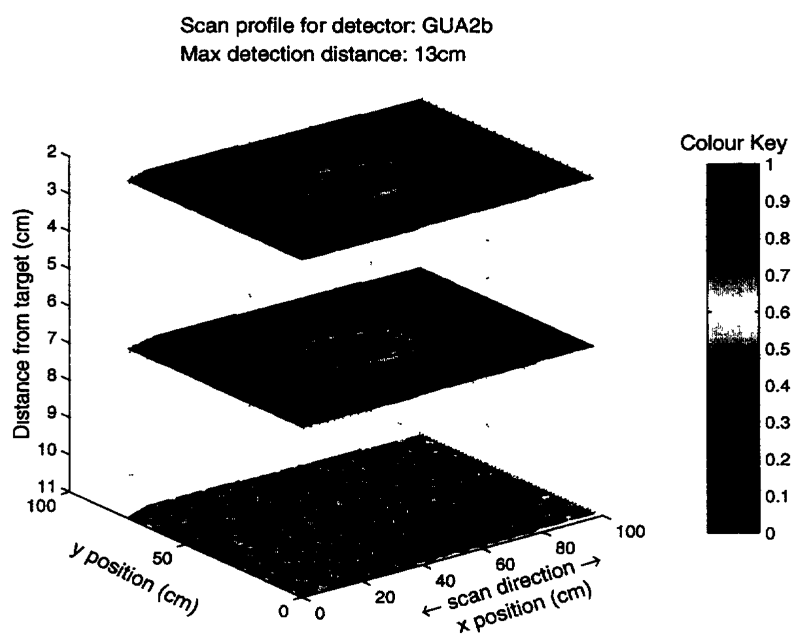

Figure 85: *Scan profiles for the Guartel MD 2000 (long probe) detector (GUA2b). Unlocked scale.*

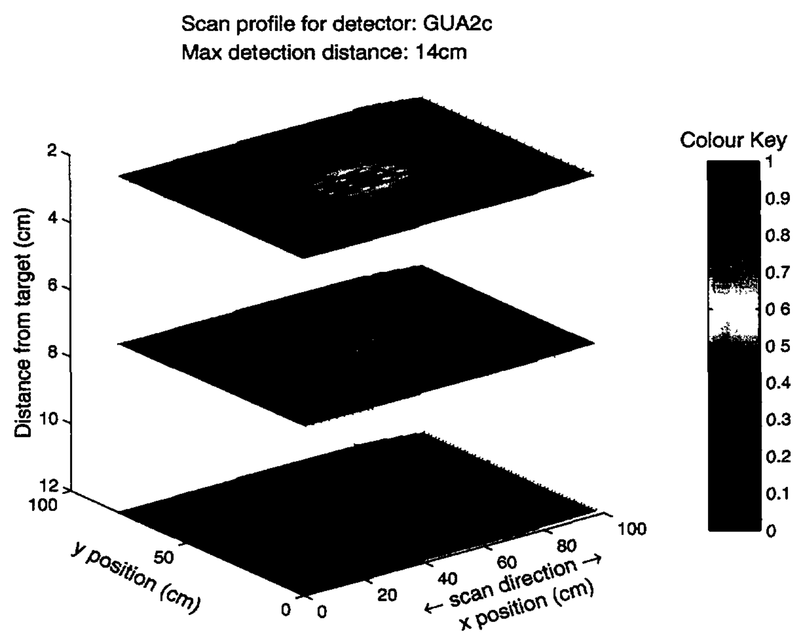

__Figure 86:__ Scan profiles for the Guartel MD 2000 (small probe) detector (GUA2c). Locked scale.

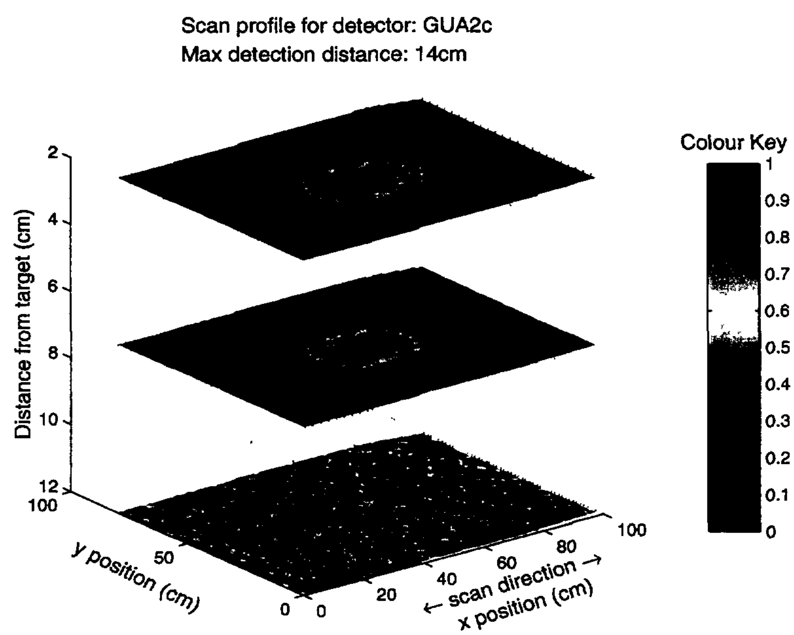

__Figure 87:__ Scan profiles for the Guartel MD 2000 (small probe) detector (GUA2c). Unlocked scale.

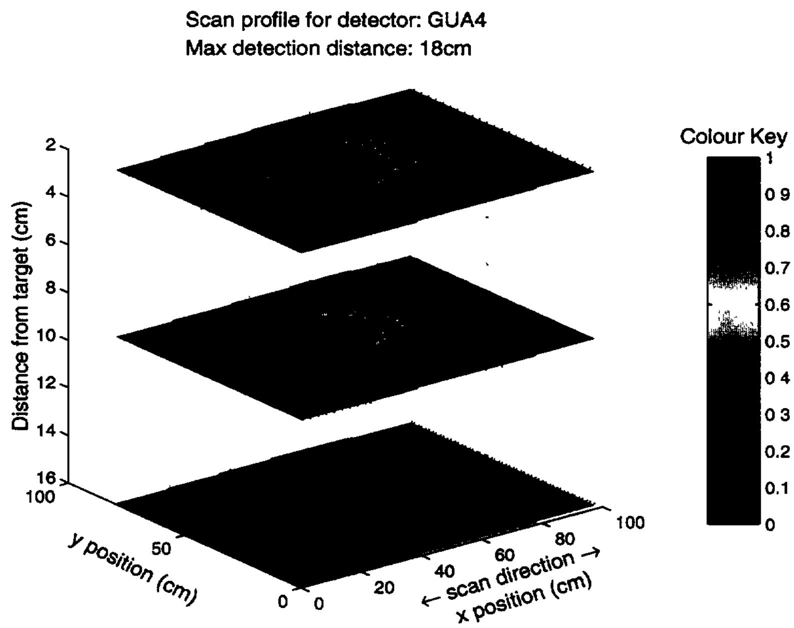

Figure 88: *Scan profiles for the Guartel MD 4 Detector (GUA4). Locked scale.*

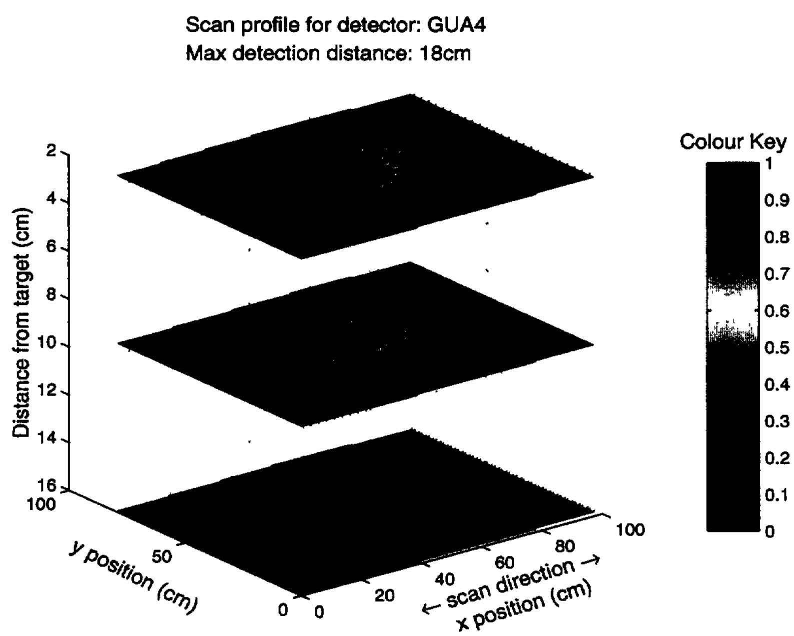

Figure 89: *Scan profiles for the Guartel MD 4 Detector (GUA4). Unlocked scale.*

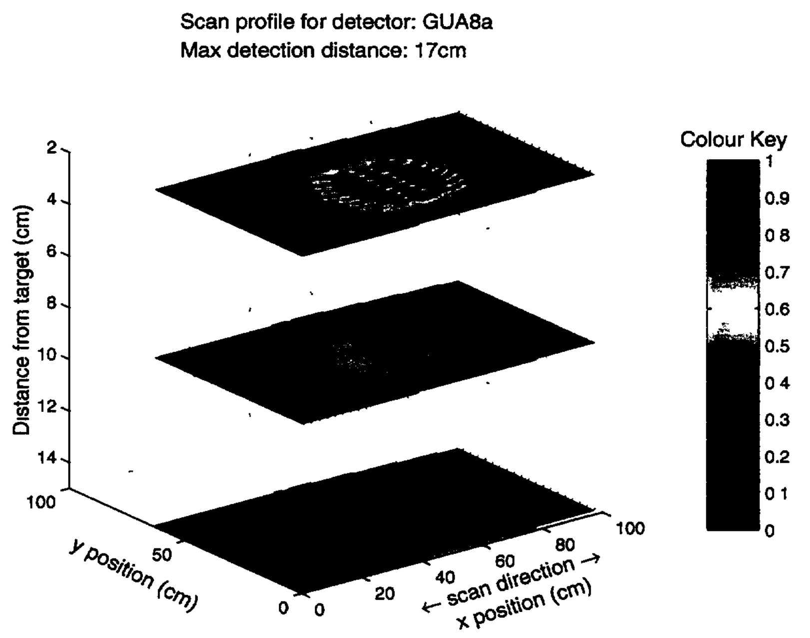

Figure 90: Scan profiles for the Guartel MD 8a (round coil) detector (GUA8a). Locked scale.

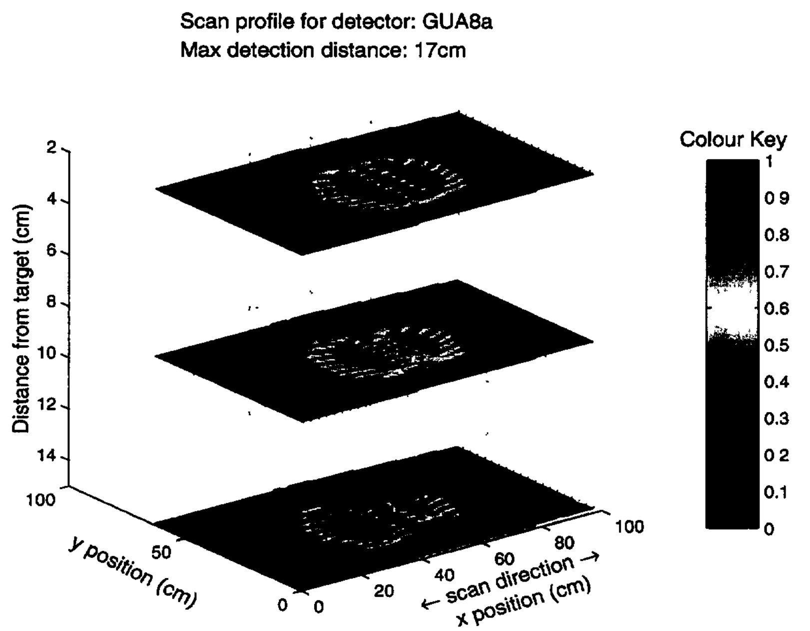

Figure 91: Scan profiles for the Guartel MD 8a (round coil) detector (GUA8a). Unlocked scale.

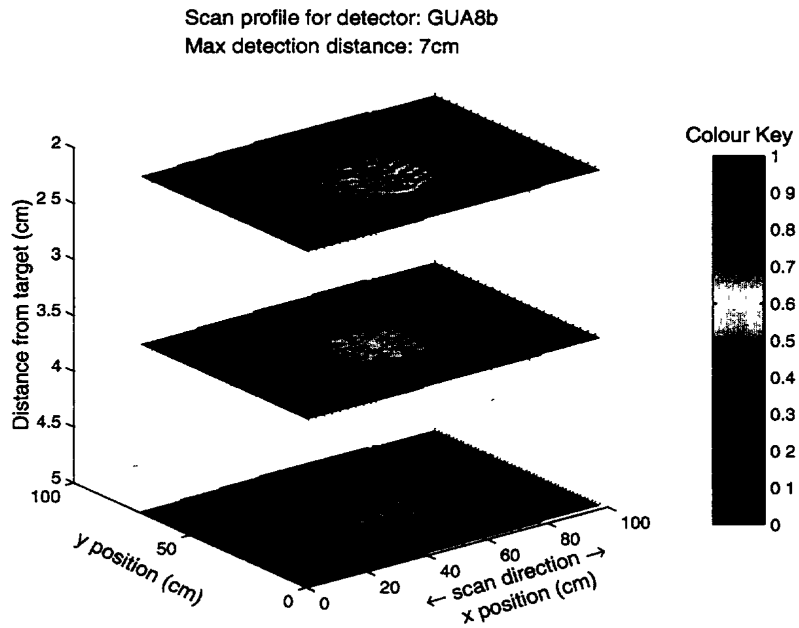

***Figure 92:** Scan profiles for the Guartel MD 8b (oval coil) detector (**GUA8b**). Locked scale.*

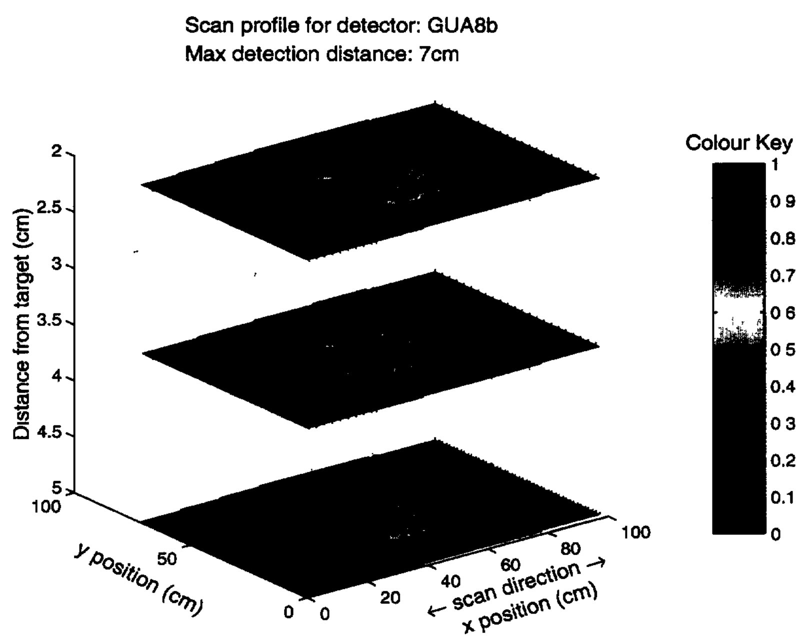

***Figure 93:** Scan profiles for the Guartel MD 8b (oval coil) detector (**GUA8b**). Unlocked scale.*

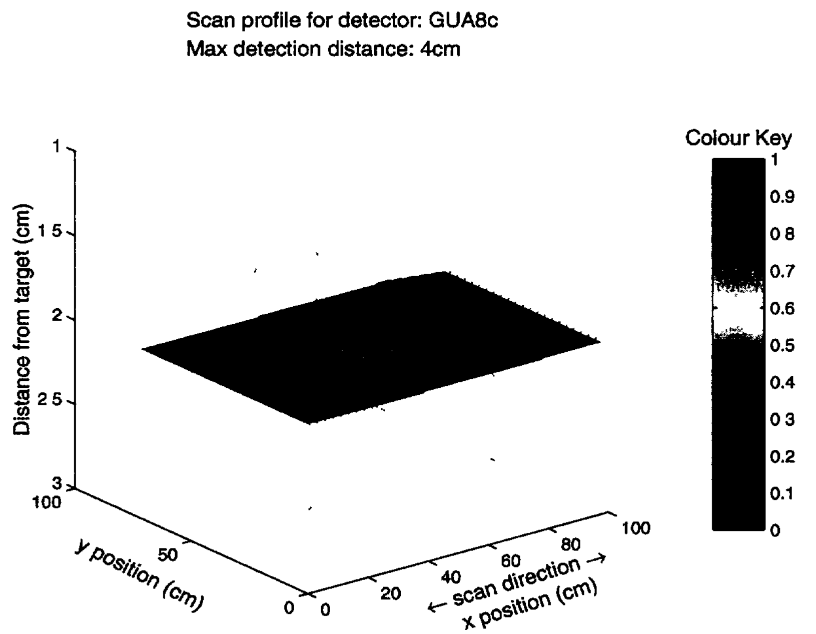

Figure 94: *Scan profiles for the Guartel MD 8c (probe) detector (GUA8c). Locked scale.*

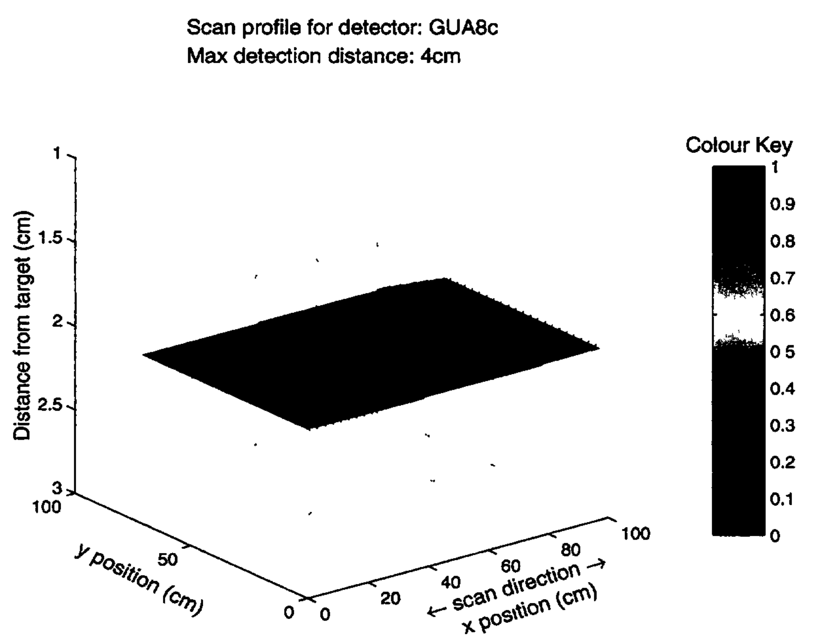

Figure 95: *Scan profiles for the Guartel MD 8c (probe) detector (GUA8c). Unlocked scale.*

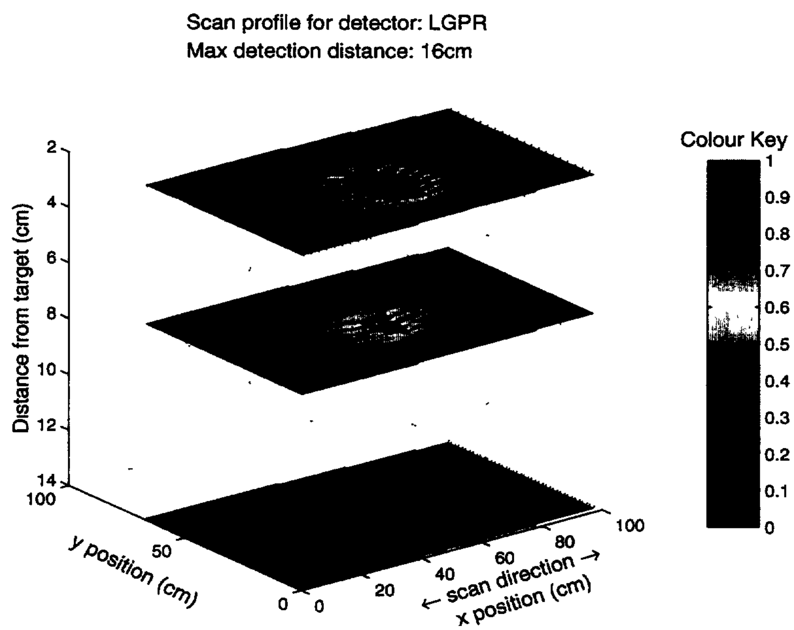

Figure 96: *Scan profiles for the LG Precision PRS 17 K detector (**LGPR**). Locked scale.*

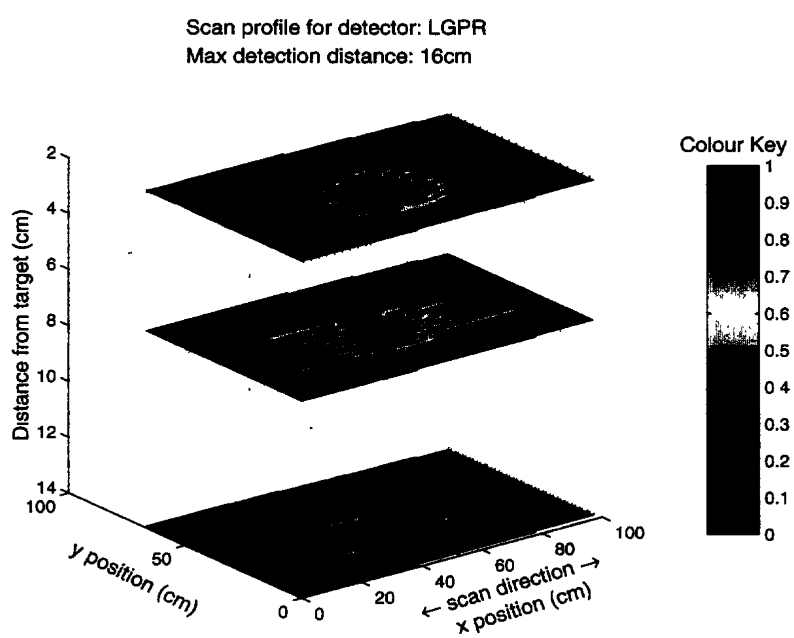

Figure 97: *Scan profiles for the LG Precision PRS 17 K detector (**LGPR**). Unlocked scale.*

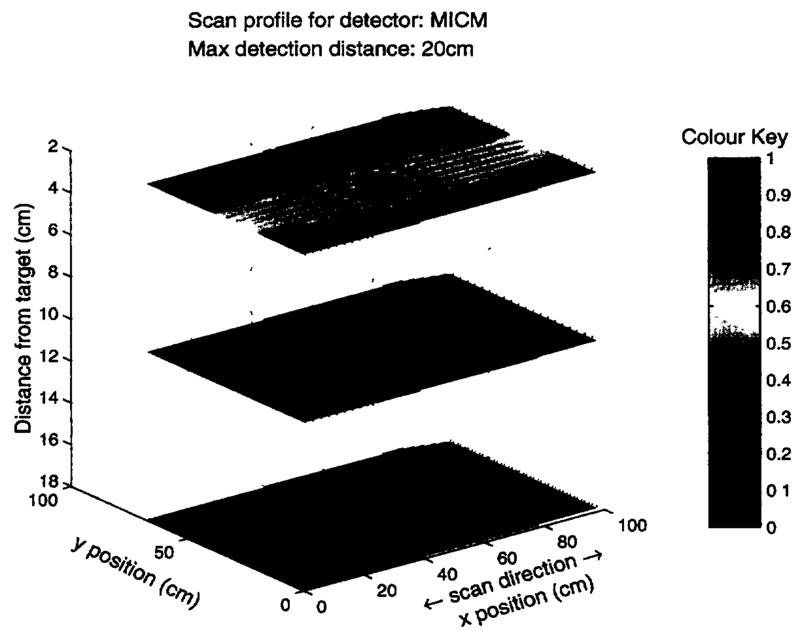

Figure 98: *Scan profiles for the Minelab F1A4-CMAC detector (MICM). Locked scale.*

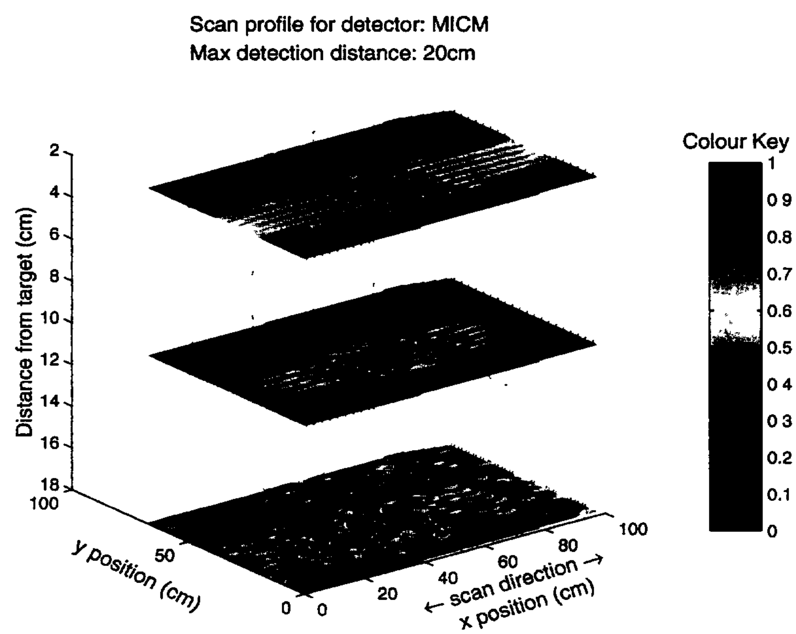

Figure 99: *Scan profiles for the Minelab F1A4-CMAC detector (MICM). Unlocked scale.*

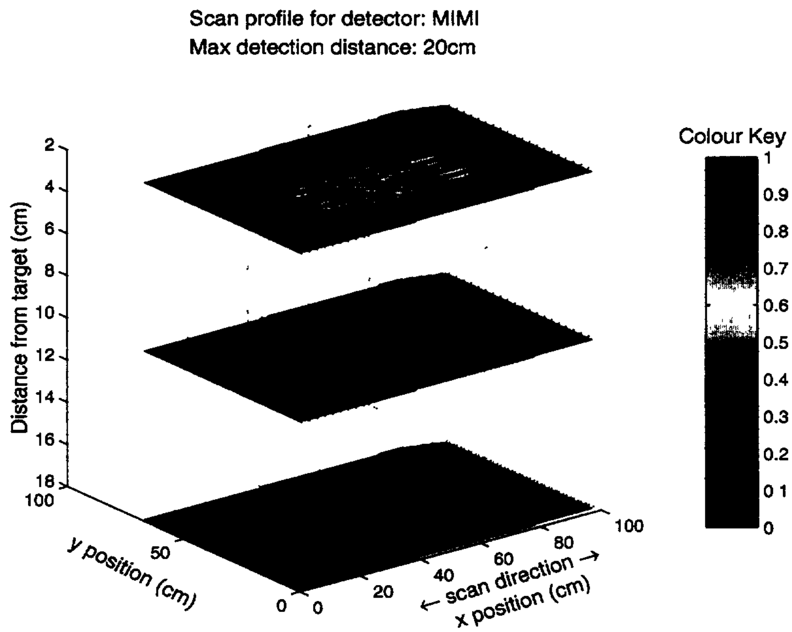

Figure 100: *Scan profiles for the Minelab F1A4-MIM detector (MIMI). Locked scale.*

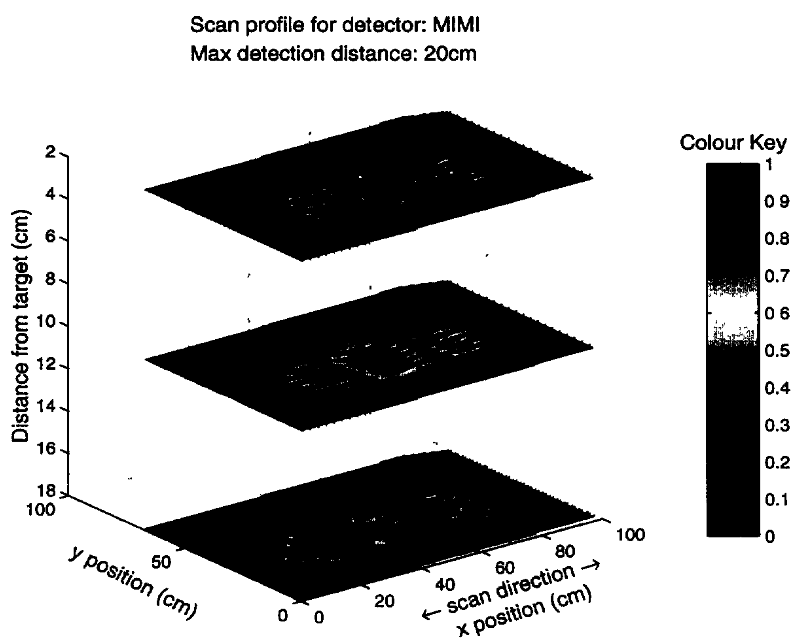

Figure 101: *Scan profiles for the Minelab F1A4-MIM detector (MIMI). Unlocked scale.*

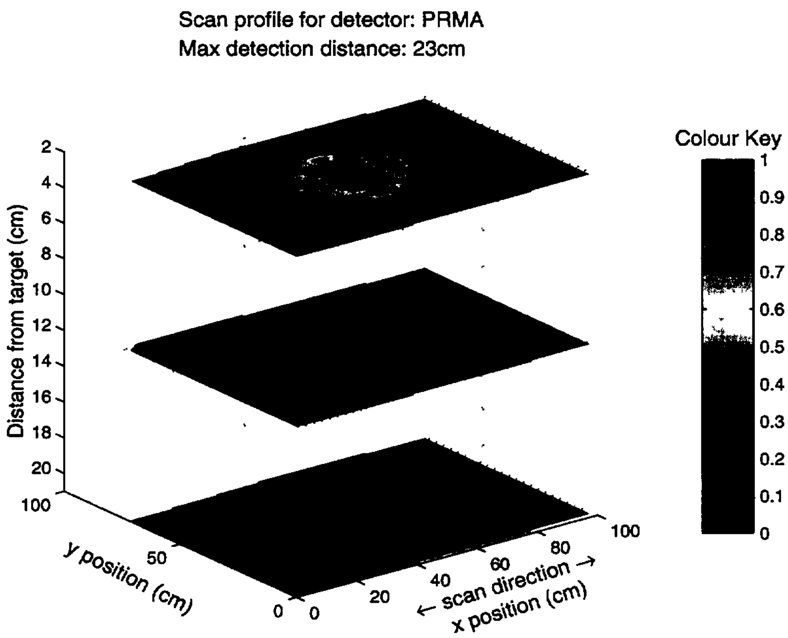

Figure 102: Scan profiles for the Pro Scan Mark 2 detector (PRMA). Locked scale.

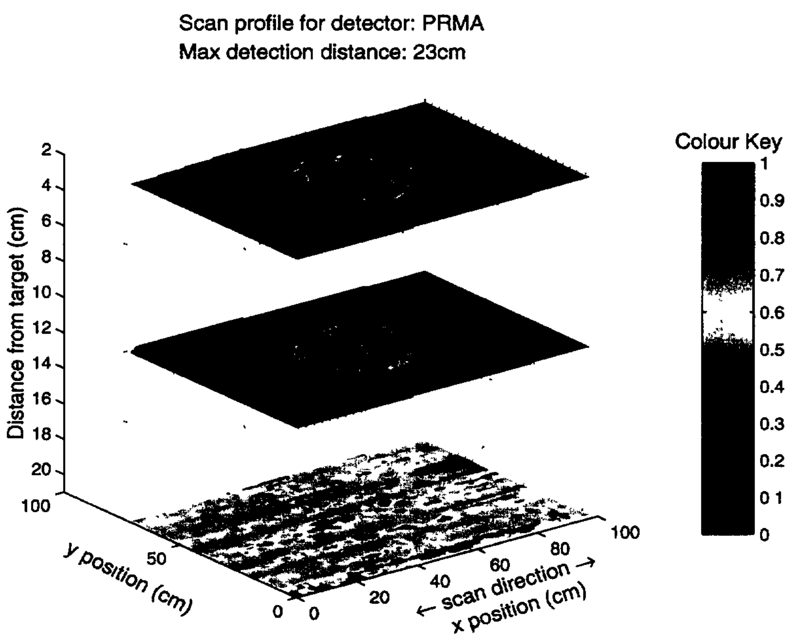

Figure 103: Scan profiles for the Pro Scan Mark 2 detector (PRMA). Unlocked scale.

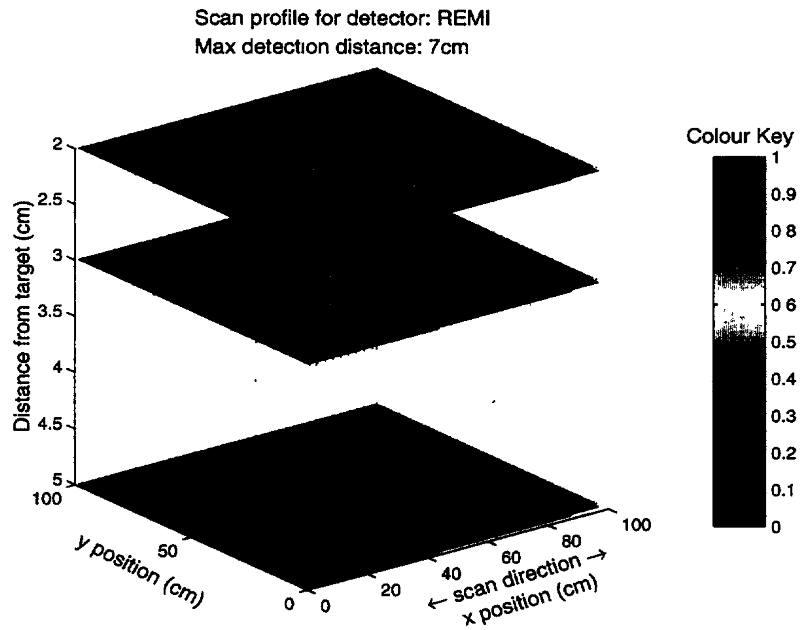

Figure 104: Scan profiles for the Reutech Midas PIMD detector (REMI). Locked scale.

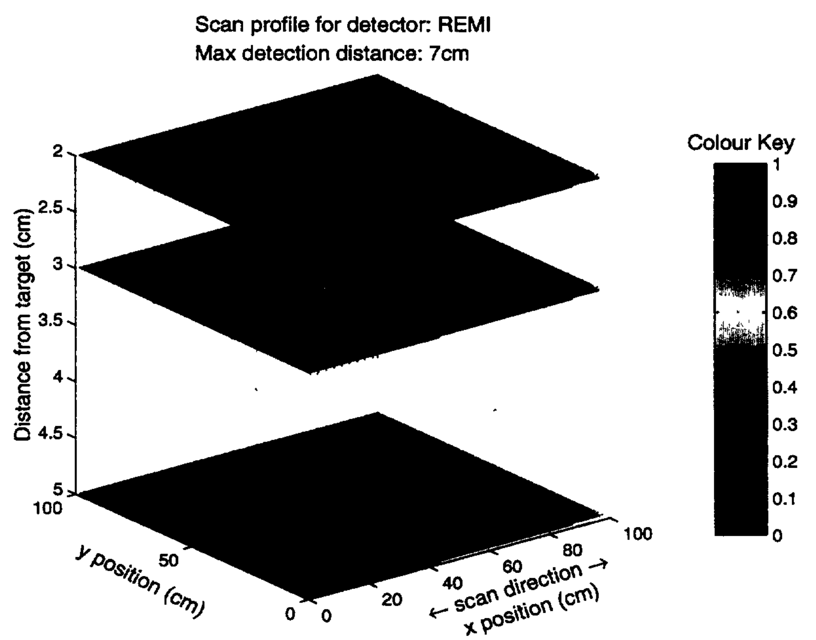

Figure 105: Scan profiles for the Reutech Midas PIMD detector (REMI). Unlocked scale.

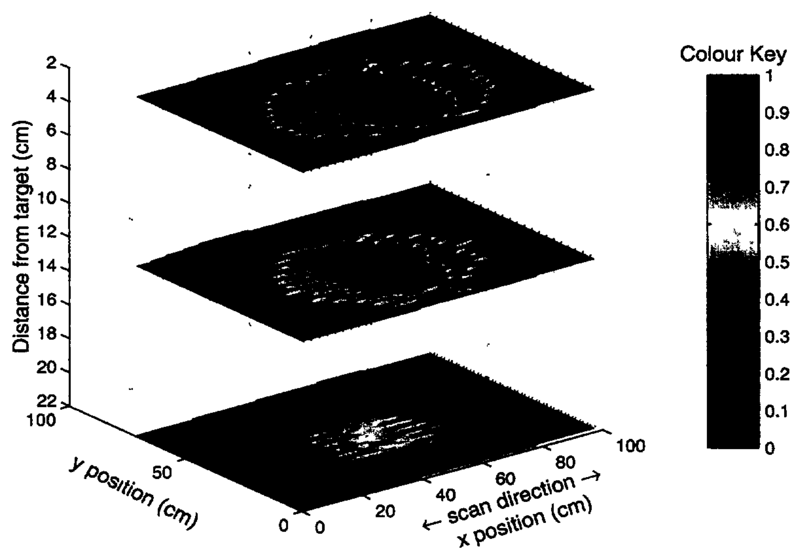

***Figure 106:** Scan profiles for the Schiebel AN19/2 detector (SCAN). Locked scale.*

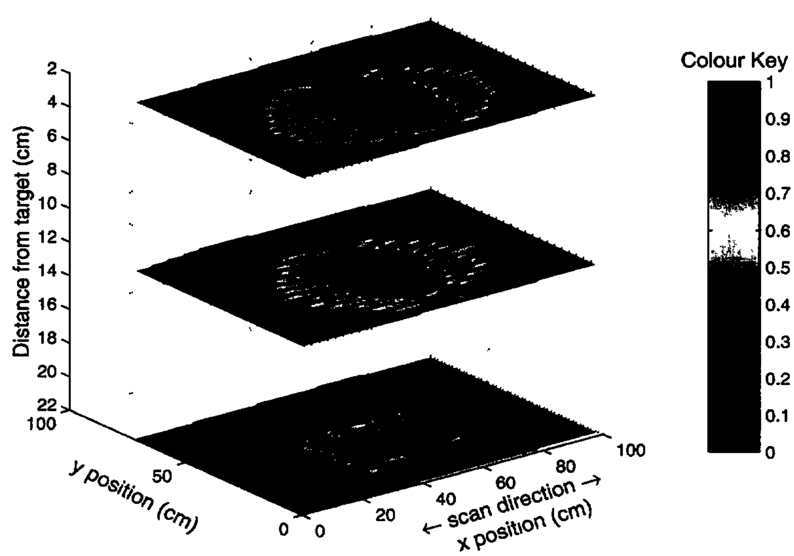

***Figure 107:** Scan profiles for the Schiebel AN19/2 detector (SCAN). Unlocked scale.*

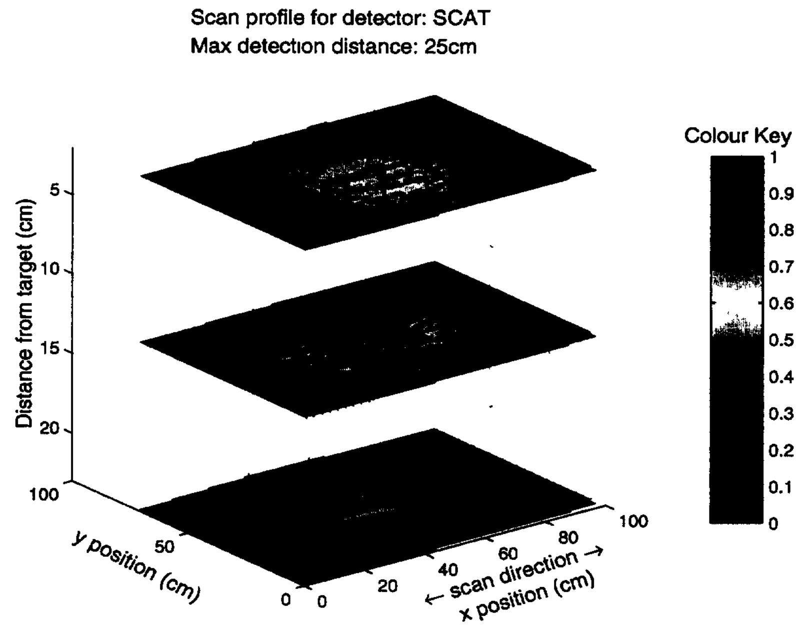

***Figure 108:** Scan profiles for the Schiebel ATMID detector (SCAT). Locked scale.*

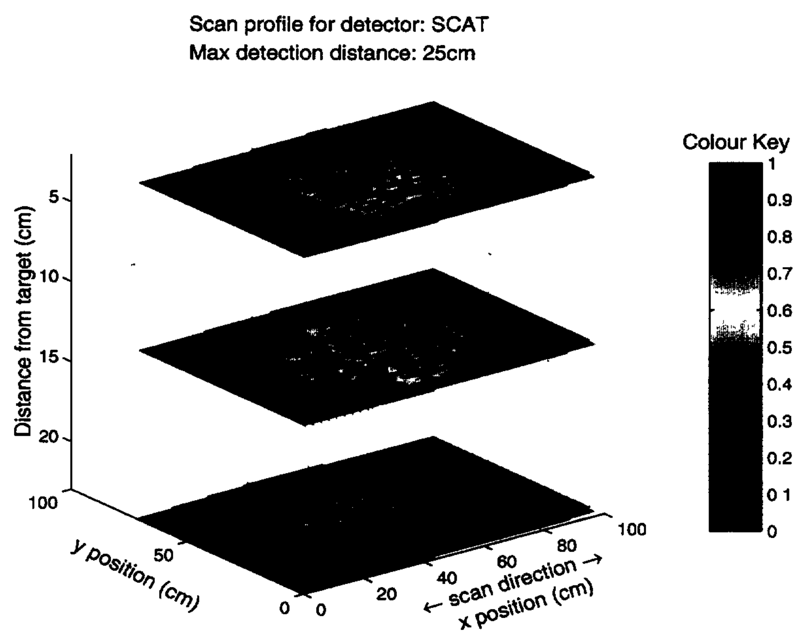

***Figure 109:** Scan profiles for the Schiebel ATMID detector (SCAT). Unlocked scale.*

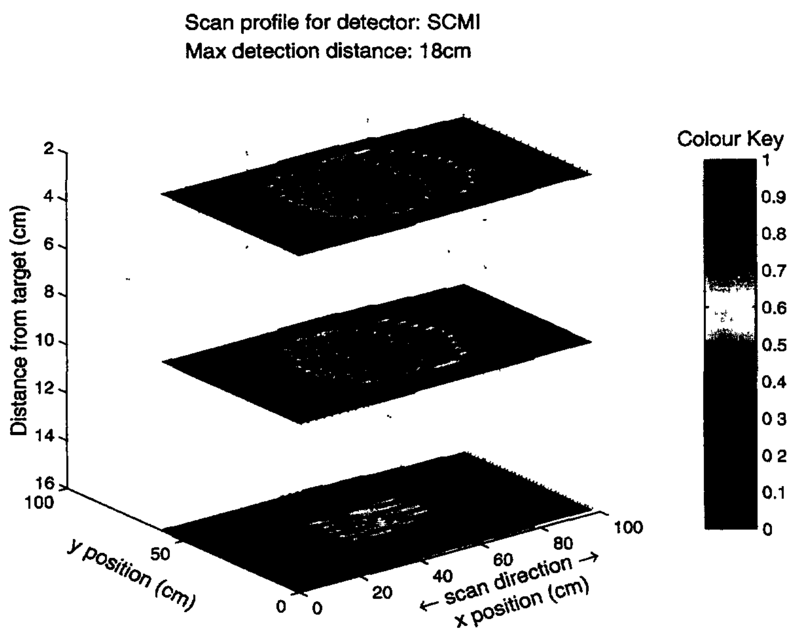

Figure 110: *Scan profiles for the Schiebel MIMID detector (SCMI). Locked scale.*

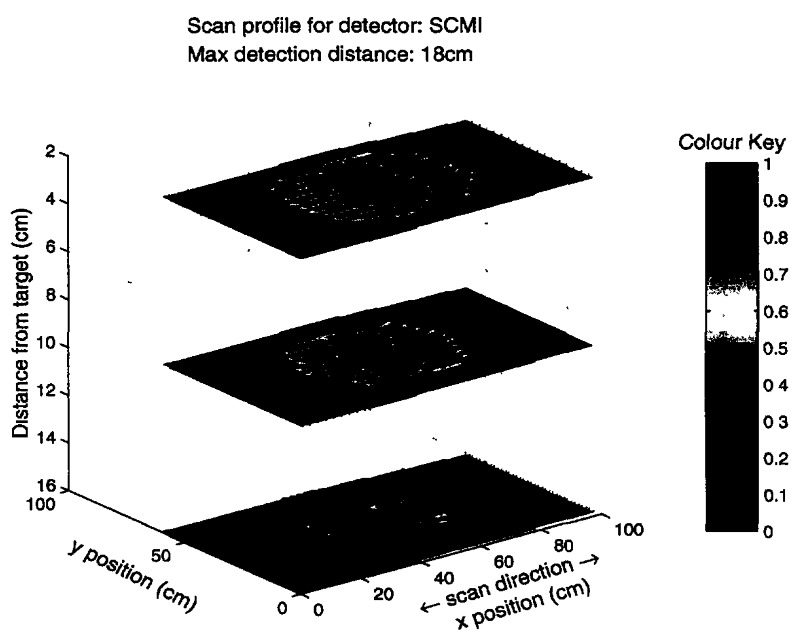

Figure 111: *Scan profiles for the Schiebel MIMID detector (SCMI). Unlocked scale.*

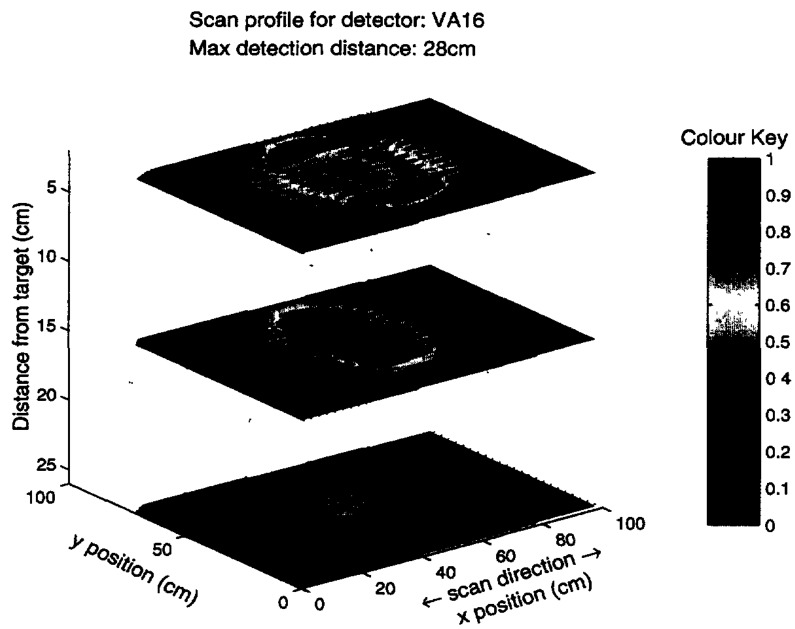

Figure 112: *Scan profiles for the Vallon ML1620C detector (VA16). Locked scale.*

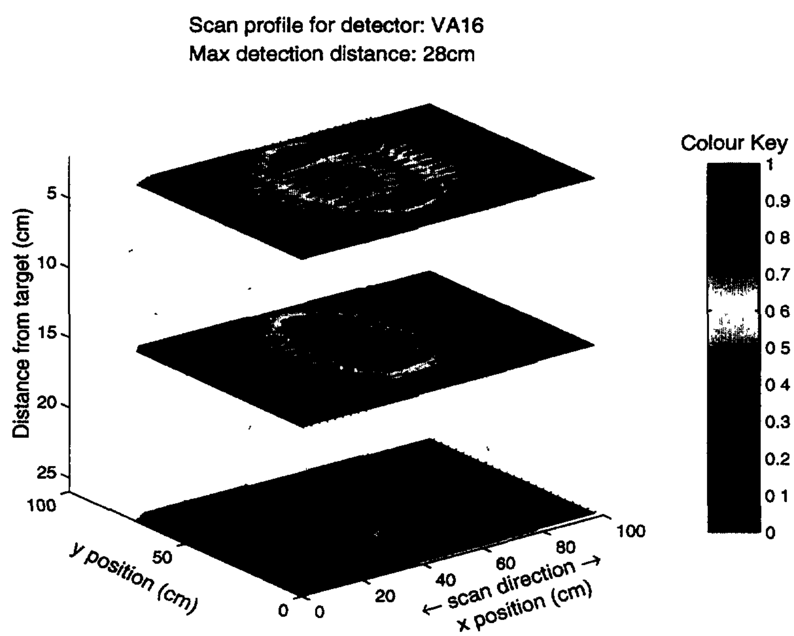

Figure 113: *Scan profiles for the Vallon ML1620C detector (VA16). Unlocked scale.*

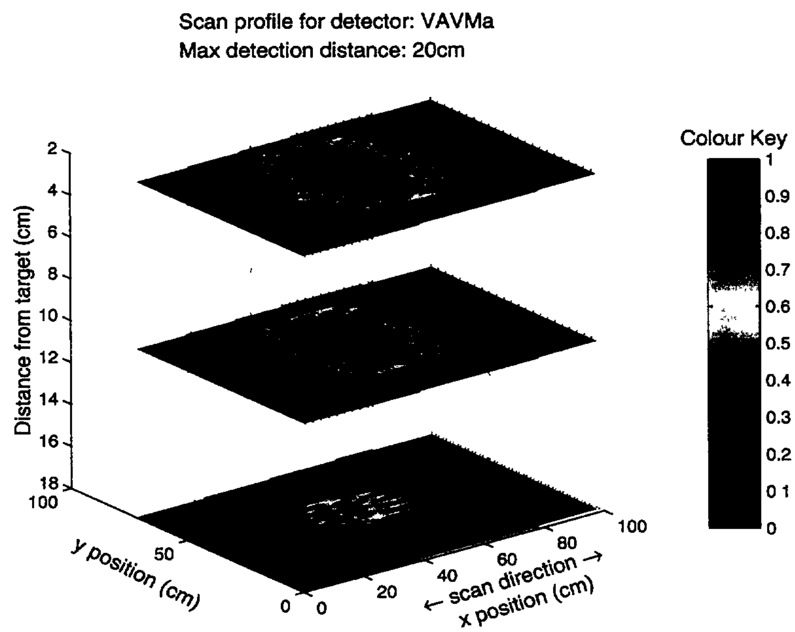

*Figure 114: Scan profiles for the Vallon VMH2 detector (**VAVMa**). Locked scale.*

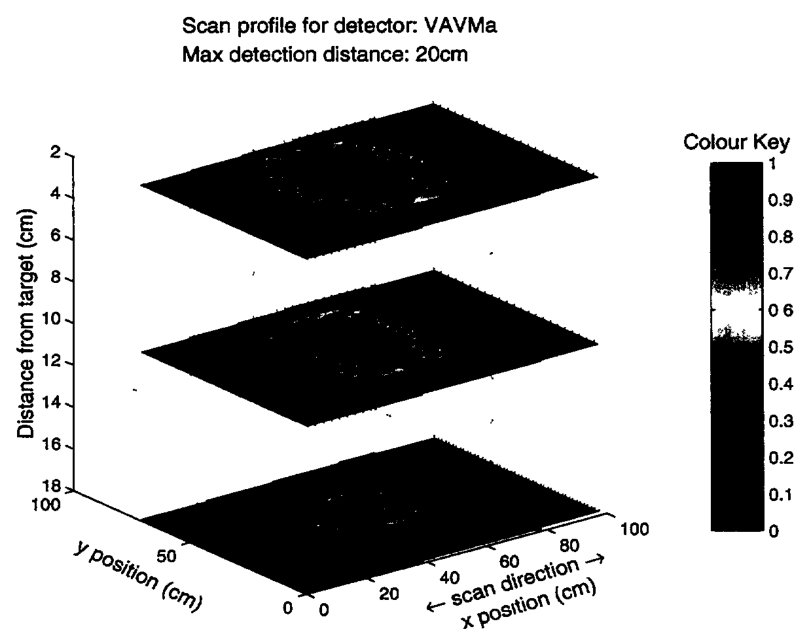

*Figure 115: Scan profiles for the Vallon VMH2 detector (**VAVMa**). Unlocked scale.*

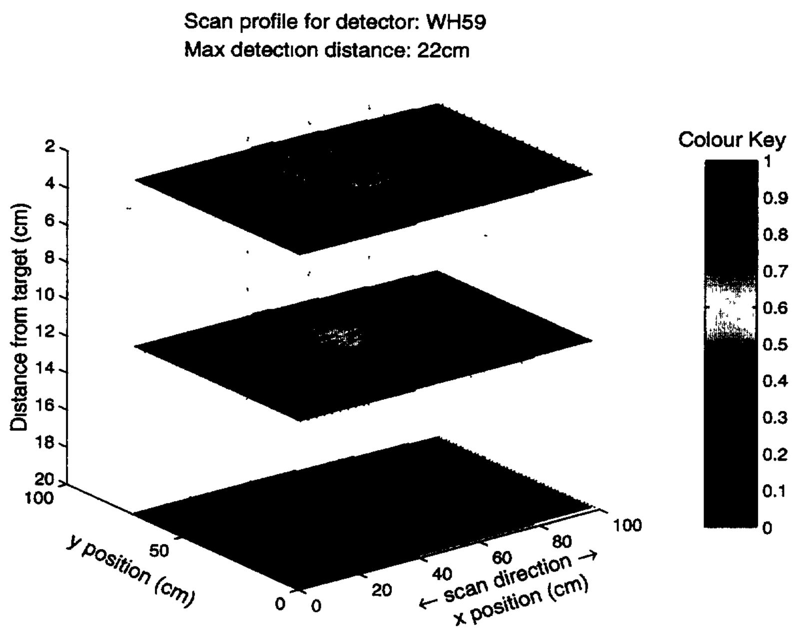

Figure 116: *Scan profiles for the White's Electronics 5900CB detector (WH59). Locked scale.*

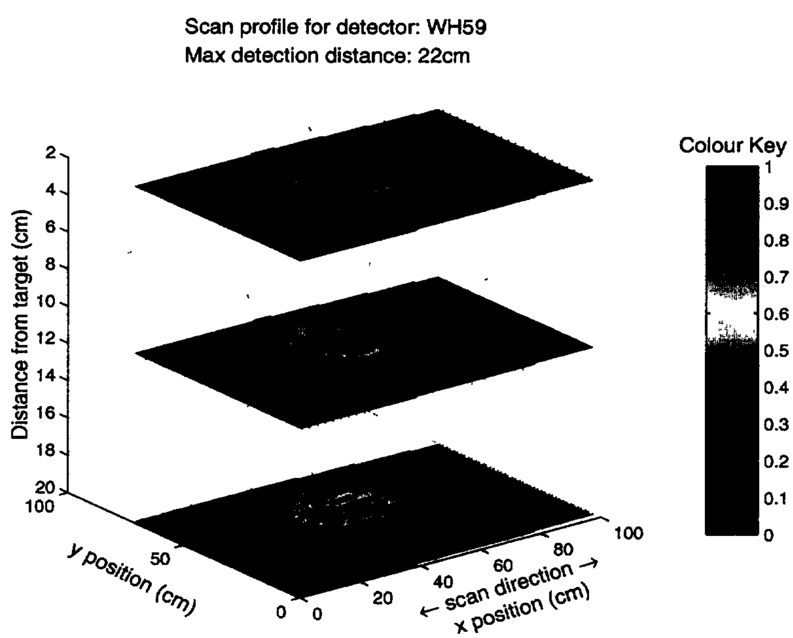

Figure 117: *Scan profiles for the White's Electronics 5900CB detector (WH59). Unlocked scale.*

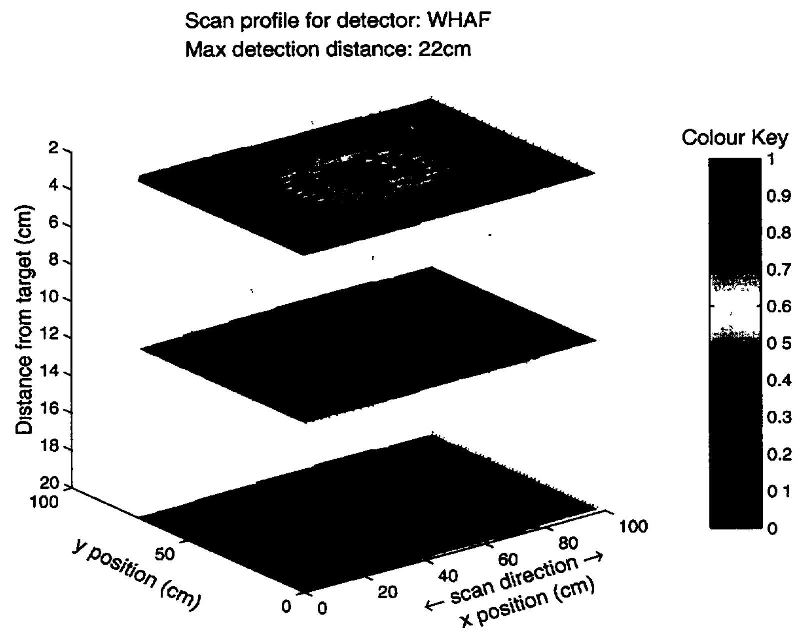

***Figure 118:** Scan profiles for the White's Electronics NATO MD AE-108 detector (WHAF). Locked scale.*

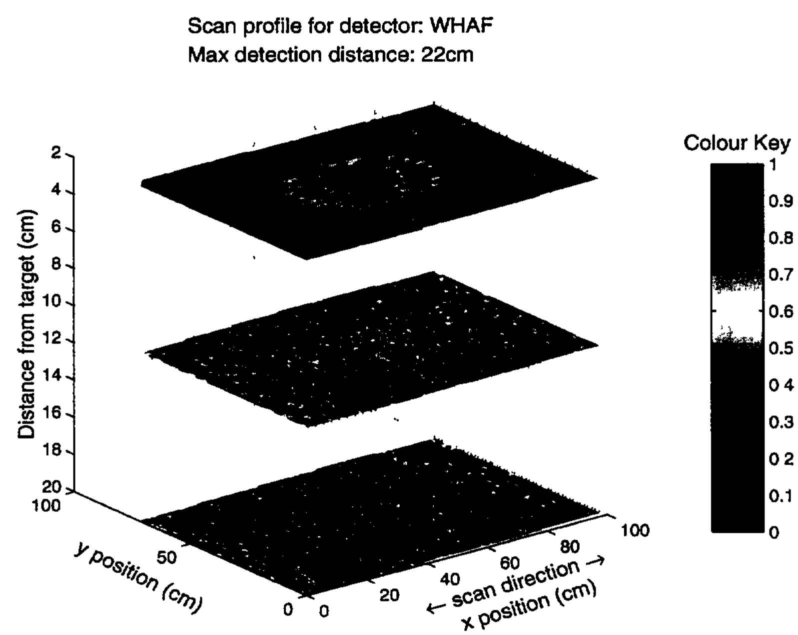

***Figure 119:** Scan profiles for the White's Electronics NATO MD AE-108 detector (WHAF). Unlocked scale.*

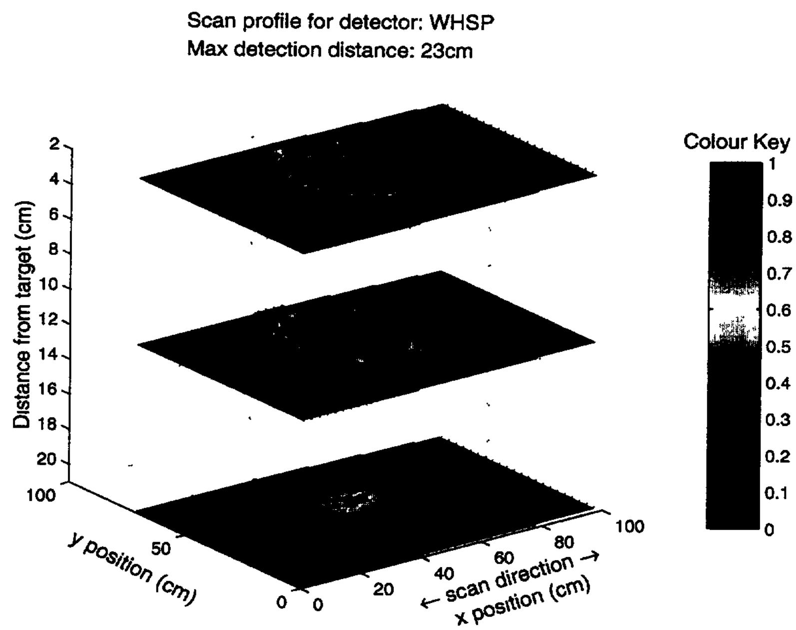

***Figure 120:** Scan profiles for the White's Electronics Spectrum XLT detector (WHSP). Locked scale.*

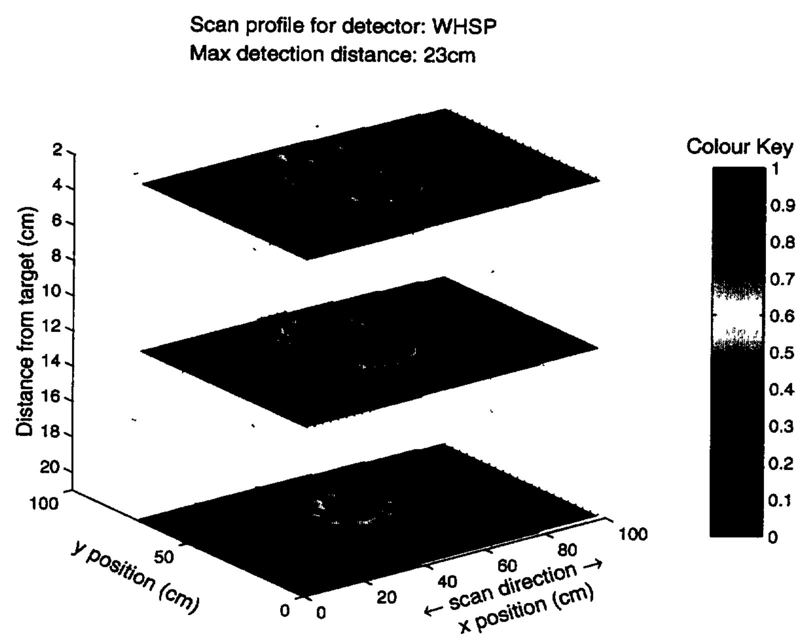

***Figure 121:** Scan profiles for the White's Electronics Spectrum XLT detector (WHSP). Unlocked scale.*

8. Summary and Conclusions

The main purpose of the In-Air Tests was to understand certain basic operational parameters of the detectors in a controlled laboratory environment. Although it is difficult to draw statistically rigorous conclusions based on the amount of data available from the In-Air Tests, the results will provide practical and useful information to the user. The In-Air Tests can be divided into three categories:

(a) Tests aimed at getting an indication of how much variation in sensitivity is to be expected due to various factors inherent in field use. The Calibration, Drift, Moisture and Sweep-Speed Tests belong to this group;

(b) This category includes the Sensitivity Test, which measures the ability of a detector to detect a variety of targets of interest; and

(c) The final category consists of the Scan Profile Test, which determines the variation of response produced by a small target as a function of its location with respect to the detector head.

The results of the tests in category (a) are summarized in Table 6, while the data have been already presented in detail in the relevant sections of the text (Section 2 to Section 4). Table 6 shows the mean and standard deviation of the maximum detection distance for each test. The means should be interpreted to give only an indication of the relative sensitivity of the different detectors. The table contains a color scheme that is briefly described in the legend. There are three shades of green that group the mean values of maximum detection distance into 0-10 cm, 10-20 cm, and greater than 20 cm. The standard deviation is highlighted with three shades of blue that group into 0-1 cm, 2 cm, and 3-5 cm. These groupings are arbitrary and only intended to assist the reader in finding those detectors in low, medium and high performance categories from the point of view of these tests. The lighter shades indicate more desirable numbers. In addition, the cells are gray where no data was collected, red where a detector failed because of a test and purple where detectors had a more general reliability problem.

There is a wide range of sensitivity among the detectors tested. The standard deviation, which indicates the expected degree of variation in sensitivity, also takes on a range of values for the detectors for a given test. For some detectors the sensitivity remained essentially constant while in others it varied significantly. Care must be exercised in using the results of the individual tests to reach conclusions about their combined effect in the field.

The Calibration and Drift Tests are considered independent of each other. On the other hand, because of the time taken to complete a Moisture Test (typically 20-30 minutes) the results from this test include some effect of drift which is difficult to separate. However, if a detector is found to have a much smaller variation in the Drift Test than in the Moisture Test, the effect of moisture can be inferred. The basic intent of the

Moisture Test was to isolate detectors that show a significant adverse effect including failure to function due to accumulated moisture on the search head.

Although we have reported the variation due to sweep speed as a standard deviation to account for a random speed, the dependence of sensitivity on sweep speed is expected to be systematic in most cases as seen in Figures 11 to 16 in Section 4. For some detectors (WH59-1, for example) the sensitivity rapidly increased with speed reaching a maximum and then decreased for higher speeds. For some others (SCAN-1, for example) sensitivity decreased monotonically with sweep speed. In still others, the sensitivity stays essentially constant. Although we did not test for it, we should note that some detectors would not detect targets when stationary. The user should make a particular point of knowing if this is the case for a chosen detector in order to develop a proper operating procedure.

The results of the category (a) tests should be used only in conjunction with those from the Sensitivity Test, repeated in Table 7, in choosing a detector. A detector with stable performance is not very useful if it cannot detect targets of interest at required distances. For example, the performance of the Adams AD2500 was found to vary very little due to the parameters tested, but its detection ranges in air for minimum-metal targets such as the PMA-2, PMA-3, Type 72A and R2M2 were well below 10 cm, which would not be satisfactory for most demining situations.

Although a detector's ability to detect targets in air does not always indicate its ability to detect targets buried in the soil, the results of the In-Air Sensitivity Test serve many useful purposes:

1. they can be used to eliminate detectors which do not have the minimum required detection distance for targets of interest because a detector is not likely to detect a target at a greater depth in soil than in air;

2. information on the relative ease of detection of the various targets can be obtained;

3. the relative sensitivity of the detectors can be compared with their performance against the same targets in soil and any major discrepancies found could be useful to manufacturers in improving their detectors; and

4. testing against a number of realistic targets will reveal any weakness due to the fact that detectors are often optimized against a single target chosen by the manufacturer.

As well, for the category (a) and (b) tests, where more than one sample of a detector is tested, the results will give some indication of the unit-to-unit variation to be expected.

Table 6: *Summary of category (a) tests: Calibration, Drift, Moisture and Sweep Speed.*

MEAN AND STANDARD DEVIATION (SD) OF MAXIMUM DETECTION DISTANCE TESTS IN CM.																
TESTS	Calibration				Drift				Moisture				Sweep Speed			
MODEL	Sample 1		Sample 2		Sample 1		Sample 2		Sample 1		Sample 2		Sample 1		Sample 2	
	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
AD25																
AD26																
[illegible]			24				23				24				23	
EB53																
FI12														3		
FIIM	25		30		28		30		22	5			28			
FIXB														3		
FOMI			24		25				24				24			
GIAT										3						
GUA2a	22		25		22		25		23				22			
GUA2b																
GUA2c																
GUA4																
GUA8a																
[illegible]																
GUA8c																
LGPR				4										3		
MICM	21		22		21		21		23				23			
MIMI	21		22		22		21		21				21			
PRMA	26		24	2	26		24		27				21			
REMI														4		
SCAN	24		27	2	25		23		22				26	3		
[illegible]	30		30	3	36		31						33			
SCMI		3														
VA16	28	3	31		28		27		26				34			
VAVMa	21		26	3			21		28				33			
WH59					28				27				29	3		
WHAF			23		21		21	3	23				21	4		
WHSP	23		25		26		25		24				27			
MAX	30	3	31	4	36		31	3	28	5	24		34	4	23	
MIN																

LEGEND				
	MEAN	NO DATA	>20	
	SD	NO DATA		3-5
		(1) All samples had failed. One working unit was made from modules of three detectors		
		(2) The sensor head is a preliminary production model and was unreliable.		
		(3) This detector failed part way through the test It recovered the following day after drying		

Table 7: *Summary of the Sensitivity Test: Maximum detection distance in cm for all targets. Only one working sample each of EB42 and GUA8b was available for testing (Section 1 7) A number in bold indicates a distance greater than that shown (Section 1.5). "No Det." indicates that the target was not detected even on contact with sensor head.*

Model	PMN	PMN-2		PMD-6	PMA-2	PMA-3	Type 72A	R2M2	M_a		I_b	G_e	STP	
	First Sample	First Sample	Second Sample	First Sample	First Sample	First Sample	First Sample	First Sample	First Sample	Second Sample	First Sample	First Sample	First Sample	Second Sample
AD25	23	13	9	11	4	7	6	5	9	11	7	5	3	3
AD26	23	10	15	9	3	6	6	4	8	10	6	4	3	5
EB42	61	34	NO DATA	30	16	16	16	9	24	NO DATA	16	12	12	NO DATA
EB53	25	13	13	12	5	7	7	2	11	8	7	4	2	1
FI12	26	14	16	11	4	5	4	0	8	9	5	2	2	3
FIIM	**26**	**26**	44	**25**	15	16	19	12	25	29	18	14	12	16
FIXB	39	22	24	20	10	12	9	7	14	15	10	7	7	8
FOMI	58	35	25	29	17	19	18	13	24	17	18	15	15	8
GIAT	30	17	22	15	5	7	8	9	9	11	5	No Dect	5	10
GUA2a	61	36	39	30	14	17	13	5	23	25	14	10	9	11
GUA2b	36	19	18	16	6	8	6	3	12	12	7	5	4	3
GUA2c	37	20	20	18	7	8	7	3	14	13	8	6	3	3
GUA4	**32**	28	23	22	10	13	11	8	17	16	12	9	8	5
GUA8a	46	27	29	22	10	14	13	9	18	19	9	10	9	11
GUA8b	22	11	NO DATA	8	2	4	3	No Dect	7	NO DATA	4	2	No Dect	NO DATA
GUA8c	15	6	6	5	No Dect	2	1	No Dect	4	4	2	No Dect	No Dect	No Dect
LGPR	43	20	21	18	9	12	7	3	13	14	9	5	2	3
MICM	46	26	28	23	12	14	15	11	22	22	15	12	5	5
MIMI	40	29	30	23	13	16	15	13	21	21	14	11	9	9
PRMA	**33**	**33**	36	28	13	15	14	6	23	23	14	6	9	10
REMI	28	13	13	10	No Dect	2	No Dect	No Dect	7	7	2	1	No Dect	No Dect
SCAN	46	38	34	32	17	18	19	10	28	24	17	12	11	10
SCAT	**47**	**47**	46	41	25	25	23	8	35	30	23	16	17	19
SCMI	**34**	29	18	21	12	12	12	5	22	14	10	10	8	2
VA16	**39**	**40**	40	**39**	22	24	23	15	34	26	23	19	20	14
VAVMa	38	35	31	30	26	18	17	10	24	22	18	13	13	8
WH59	**44**	33	23	27	16	18	23	7	23	16	17	12	12	6
WHAF	**45**	37	34	28	12	11	11	4	21	22	11	6	6	7
WHSP	**44**	35	36	29	15	20	17	14	23	23	17	18	16	14
MAX	61	47	46	41	26	25	23	15	35	30	23	19	20	19
MIN	15	6	6	5	No Dect	2	No Dect	No Dect	4	4	2	No Dect	No Dect	No Dect

The results from the Scan Profile Test will help the user understand the general shape of the effective "detection volume" of each detector. Our measurements showed that the detector footprint generally becomes smaller as the target distance increases, resulting in a cone-shaped "detection volume". For the small target, typical of minimum-metal mines, this general trend of shrinking footprint with distance was observed for all the detectors tested. This finding is contrary to claims by some manufacturers. Although our data will help the user adjust his training and Standard Operating Procedures (SOPs), in order to make quantitative use of footprint data they should be measured more precisely and for a number of targets of interest.

The main purpose of the In-Air Tests was to understand certain basic operational parameters of the detectors in a controlled laboratory environment. The primary use of the results of these tests would be in avoiding detectors that are obviously inadequate and in guiding the user in developing proper training and SOPs regardless of the detector selected for deployment. As well, the data from these tests should be used in conjunction with the other tests to choose suitable detectors for a given situation.

For future in-air tests, techniques should be devised for eliminating the effect of an operator on test results. This may be through the development of computerized algorithms to make "detection" decisions or through the use of a random sample of operators on the same data. As well, all tests should be repeated a number of times. This will allow more rigorous analysis of data collected.

Future evaluations of this nature should also consider conducting at least three additional tests. These are:

1. power consumption and any effect of battery state on detector performance;
2. effect of temperature and humidity on detector performance; and
3. effect of ambient electromagnetic noise on detector performance.

References

1. IPPTC (1999). The Terms of Reference, International Pilot Project for Technology Co-operation (IPPTC). IPPTC working document (unpublished draft).
2. Schoolderman, A.J. and de Wolf, F.J. (1999). International Pilot Project for Technology Cooperation: Test Plan for Soil Tests. TNO Physics and Electronics Laboratory (TNO-FEL). (Technical Report TNO Report FEL-99-C253). The Hague, Netherlands.
3. Das, Y. and Toews, J.D. (2000). A Plan for In-air Testing of Metal Detectors. (DRES TM 2000-184). Defence Research Establishment Suffield.
4. Das, Y. and Toews, J. D. (1998). Issues in performance evaluation of metal detectors. In *Proc. UXO Forum '98*, Anaheim, California. (CD-ROM).

5. King, C., (Ed.) (1998/99). Jane's Mines and Mine Clearance, 3rd ed. Surrey, U.K.: Jane's.

6. Ess, R. Private Communication. A description of these targets are also available on the following Webpage (search for "simulants" and follow links). http://www.uxocoe.brtrc.com/TecReports.htm (5 Dec. 2000).

7. Das, Y., Toews, J.D., Rutkay, D., and McFee, J.E. (1996). Effect of Water on Canadian Forces' AN19/2 Mine Detector. (Suffield Memorandum No.1484). Defence Research Establishment Suffield.

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Canada participated in the International Pilot Project for Technology Co-operation (IPPTC) in landmine detection under the auspices of the Canadian Centre for Mine Action Technologies (CCMAT). The goal of this multinational project was to conduct various laboratory and field tests on a number of commercial metal detectors in their use as mine detectors. Results of these tests will provide relevant information to potential sponsors and end users of such technology to help them make informed decisions about their equipment selection and use in humanitarian demining. This report presents the results of in-air laboratory tests, designed and led by Canada, and conducted at the Defence Research Establishment Suffield.

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